Annual Report of the Board of Regents of THE SMITHSONIAN INSTITUTION

Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended

June 30, 1948

(Publication 3954)

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LETTER OF TRANSMITTAL

Smithsonian Institution,
Washington, December 10, 1948.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1948. I have the honor to be,

Respectfully,

A. Wetmore, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1948

Presiding Officer ex officio.—HARRY S. TRUMAN, President of the United States.
Chancellor.—FRED M. VINSON, Chief Justice of the United States.
Members of the Institution:
HARRY S. TRUMAN, President of the United States.
——— Vice President of the United States.
FRED M. VINSON, Chief Justice of the United States.
GEORGE C. MARSHALL, Secretary of State.
JOHN W. SNYDER, Secretary of the Treasury.
JAMES FORRESTAL, Secretary of Defense.
TOM C. CLARK, Attorney General.
JESSE M. DONALDSON, Postmaster General.
JULIUS A. KRUG, Secretary of the Interior.
CHARLES F. BRANNON, Secretary of Agriculture.
CHARLES SAWYER, Secretary of Commerce.
——— Secretary of Labor.
Regents of the Institution:
FRED M. VINSON, Chief Justice of the United States, Chancellor.
——— Vice President of the United States.
ALBEN W. BARKLEY, Member of the Senate.
WALLACE H. WHITE, Jr., Member of the Senate.
WALTER F. GEORGE, Member of the Senate.
CLARENCE CANNON, Member of the House of Representatives.
SAMUEL K. MCCONNELL, Jr., Member of the House of Representatives.
JOHN M. VORYS, Member of the House of Representatives.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Missouri.
VANNEVAR BUSH, citizen of Washington, D. C.
ROBERT V. FLEMING, citizen of Washington, D. C.
Executive Committee.—ROBERT V. FLEMING, VANNEVAR BUSH, CLARENCE CANNON.
Secretary.—ALEXANDER WETMORE.
Assistant Secretary.—JOHN E. GRAF.
Assistant Secretary.—J. L. KEDDY.
Treasurer.—J. D. HOWARD.
Chief, editorial division.—WEBSTER P. TRUE.
Librarian.—LEILA F. CLARK.
Administrative accountant.—THOMAS F. CLARK.
Personnel officer.—B. T. CARWITHEN.
Chief, publications division.—L. E. COMMERFORD.
Purchasing officer.—ANTHONY W. WILDING.

UNITED STATES NATIONAL MUSEUM

Director.—A. REMINGTON KELLOGG.

SCIENTIFIC STAFF

DEPARTMENT OF ANTHROPOLOGY:

Frank M. Setzler, head curator; A. J. Andrews, chief preparator.

Collaborator in anthropology: W. W. Taylor, Jr.

Division of Archeology: Neil M. Judd, curator; Waldo R. Wedel, associate curator; M. C. Blaker, scientific aid; J. Townsend Russell, honorary assistant curator of Old World archeology.

Division of Ethnology: H. W. Krieger, curator; J. C. Ewers, associate curator; R. A. Elder, Jr., assistant curator.

Division of Physical Anthropology: T. Dale Stewart, curator; M. T. Newman, associate curator.

DEPARTMENT OF ZOOLOGY:

Waldo L. Schmitt, head curator; W. L. Brown, chief taxidermist; Aime M. Awl, illustrator.

Associates in Zoology: T. S. Palmer, W. B. Marshall, A. G. Böving, C. R. Shoemaker.

Collaborator in Zoology: R. S. Clark.

Collaborator in Biology: D. C. Graham.

Division of Mammals: D. H. Johnson, associate curator; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator; Alexander Wetmore, custodian of alcoholic and skeleton collections; Arthur C. Bent, collaborator.

Division of Reptiles and Amphibians: Doris M. Cochran, zoologist.

Division of Fishes: Leonard P. Schultz, curator; R. R. Miller, associate curator; L. P. Woods, associate curator; D. S. Erdman, scientific aid; W. T. Leapley, scientific aid.

Division of Insects: L. O. Howard, honorary curator; Edward A. Chapin, curator; R. E. Blackwelder, associate curator; W. D. Field, associate curator; Grace E. Glance, associate curator; W. L. Jellison, collaborator.

Section of Hymenoptera: S. A. Rohwer, custodian; W. M. Mann, assistant custodian; Robert A. Cushman, assistant custodian.

Section of Myriapoda: O. F. Cook, custodian.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Section of Lepidoptera: J. T. Barnes, collaborator.

Section of Forest Tree Beetles: A. D. Hopkins, custodian.

Division of Marine Invertebrates: F. A. Chace, Jr., curator; P. L. Illg, associate curator; Frederick M. Bayer, assistant curator; Mrs. Harriet Richardson Searle, collaborator; Max M. Ellis, collaborator; J. Percy Moore, collaborator; Joseph A. Cushman, collaborator in Foraminifera; Mrs. M. S. Wilson, collaborator in copepod Crustacea.

Division of Mollusks: Harald A. Rehder, curator; Joseph P. E. Morrison, associate curator; R. Tucker Abbott, assistant curator; W. J. Byas, museum aid; P. Bartsch, associate.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Division of Echinoderms: Austin H. Clark, curator.

DEPARTMENT OF BOTANY (NATIONAL HERBARIUM):

E. P. Killip, head curator; Henri Pittier, associate in botany.

Division of Phanerogams: A. C. Smith, curator; E. C. Leonard, associate curator; C. V. Morton, associate curator; E. H. Walker, associate curator; Lyman B. Smith, associate curator.

Division of Grasses: Jason R. Swallen, curator; Agnes Chase, research associate; F. A. McClure, research associate.

Division of Cryptogams: E. P. Killip, acting curator; Paul S. Conger, associate curator; G. A. Llano, associate curator; O. F. Cook, assistant curator; John A. Stevenson, custodian of C. G. Lloyd mycological collections; W. T. Swingle, custodian of Higher Algae; David Fairchild, custodian of Lower Fungi.

DEPARTMENT OF GEOLOGY:

R. S. Bassler, head curator; J. H. Benn, exhibits preparator; Jessie G. Beach, aid.

Division of Mineralogy and Petrology: W. F. Foshag, curator; E. P. Henderson, associate curator; G. S. Switzer, associate curator; B. O. Reberholt, exhibits preparator; Frank L. Hess, custodian of rare metals and rare earths.

Division of Invertebrate Paleontology and Paleobotany: Gustav A. Cooper, curator; A. R. Loeblich, Jr., associate curator; A. L. Bowsher, associate curator; J. Brookes Knight, research associate in Paleontology.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; J. B. Reeside, Jr.. custodian of Mesozoic collection.

Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, associate curator; Norman H. Boss, chief exhibits preparator; A. C. Murray, F. L. Pearce, preparators.

Associates in Mineralogy: W. T. Schaller, S. H. Perry, J. P. Marble.

Associate in Paleontology: T. W. Vaughan.

Associate in Petrology: Whitman Cross.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Frank A. Taylor, head curator.

Division of Engineering: Frank A. Taylor, acting curator.

Section of Civil and Mechanical Engineering: Frank A. Taylor, in charge.

Section of Marine Transportation: Frank A. Taylor, in charge.

Section of Electricity: K. M. Perry, associate curator.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Land Transportation: S. H. Oliver, associate curator.

Division of Crafts and Industries: W. N. Watkins, curator; F. C. Reed, associate curator; E. A. Avery, museum aid; F. L. Lewton, research associate.

Section of Textiles: G. L. Rogers, assistant curator.

Section of Wood Technology: William N. Watkins, in charge.

Section of Manufactures: F. C. Reed, in charge.

Section of Agricultural Industries: F. C. Reed, in charge.

Division of Medicine and Public Health: G. S. Thomas, associate curator.

Division of Graphic Arts: J. Kainen, curator; E. J. Fite, museum aid.

Section of Photography: A. J. Wedderburn, Jr., associate curator.

DIVISION OF HISTORY: T. T. Belote, curator; Charles Carey, associate curator; M. L. Peterson. associate curator; M. W. Brown, assistant curator; J. Russell Sirlouis, scientific aid.

Section of Civil History: T. T. Belote, in charge.

Section of Military History: C. Carey, in charge.

Section of Naval History: C. Carey, in charge.

Section of Numismatics: T. T. Belote, in charge.

Section of Philately: C. L. Manning, assistant curator.

ADMINISTRATIVE STAFF

Chief, office of correspondence and records.—H. S. Bryant.
Superintendent of buildings and labor.—L. L. Oliver.
Assistant superintendent of buildings and labor.—Charles C. Sinclair.
Editor.—Paul H. Oehser.
Accountant and auditor.—T. F. Clark.
Photographer.—F. B. Kestner.
Purchasing officer.—A. W. Wilding.
Assistant librarian.—Elisabeth H. Gazin.

NATIONAL GALLERY OF ART

Trustees:

Fred M. Vinson, Chief Justice of the United States, *Chairman.*
George C. Marshall, Secretary of State.
John W. Snyder, Secretary of the Treasury.
Alexander Wetmore, Secretary of the Smithsonian Institution.
Samuel H. Kress.
Ferdinand Lammot Belin.
Duncan Phillips.
Chester Dale.
Paul Mellon.

President.—Samuel H. Kress.
Vice President.—Ferdinand Lammot Belin.
Secretary-Treasurer.—Huntington Cairns.
Director.—David E. Finley.
Administrator.—Harry A. McBride.
General Counsel.—Huntington Cairns.
Chief Curator.—John Walker.
Assistant Director.—Macgill James.

NATIONAL COLLECTION OF FINE ARTS

Director.—Thomas M. Beggs; G. J. Martin, exhibits preparator.

FREER GALLERY OF ART

Director.—A. G. Wenley.
Assistant Director.—J. A. Pope.
Research associate.—Grace Dunham Guest.
Associate in Near Eastern art.—Richard Ettinghausen.
Associate in Far Eastern art.—W. R. B. Acker.

BUREAU OF AMERICAN ETHNOLOGY

Director.—Matthew W. Stirling.
Associate Director.—Frank H. H. Roberts, Jr.
Senior ethnologists.—H. B. Collins, Jr., John P. Harrington, W. N. Fenton.
Senior anthropologists.—G. R. Willey, P. Drucker.
Collaborators.—Frances Densmore, John R. Swanton, A. J. Waring, Jr.
Editor.—M. Helen Palmer.
Librarian.—Miriam B. Ketchum.
Illustrator.—Edwin G. Cassedy.
Institute of Social Anthropology.—G. M. Foster, Jr., *Director.*
River Basin Surveys.—Frank H. H. Roberts, Jr., *Director.*

INTERNATIONAL EXCHANGE SERVICE

Acting Chief.—D. G. WILLIAMS.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.
Assistant Director.—ERNEST P. WALKER.
Head Keeper.—FRANK O. LOWE.

ASTROPHYSICAL OBSERVATORY

Director.—LOYAL B. ALDRICH.
DIVISION OF ASTROPHYSICAL RESEARCH:
Chief.—WILLIAM H. HOOVER.
Instrument makers.—D. G. TALBERT, J. H. HARRISON.
Research associate.—CHARLES G. ABBOT.
DIVISION OF RADIATION AND ORGANISMS:
Acting chief, in charge.—LOYAL B. ALDRICH.
Biologist (biophysicist).—LEONARD PRICE.
Chemist.—O. J. WILLIAMS.
Biological aid (botany).—V. B. ELSTAD.

NATIONAL AIR MUSEUM

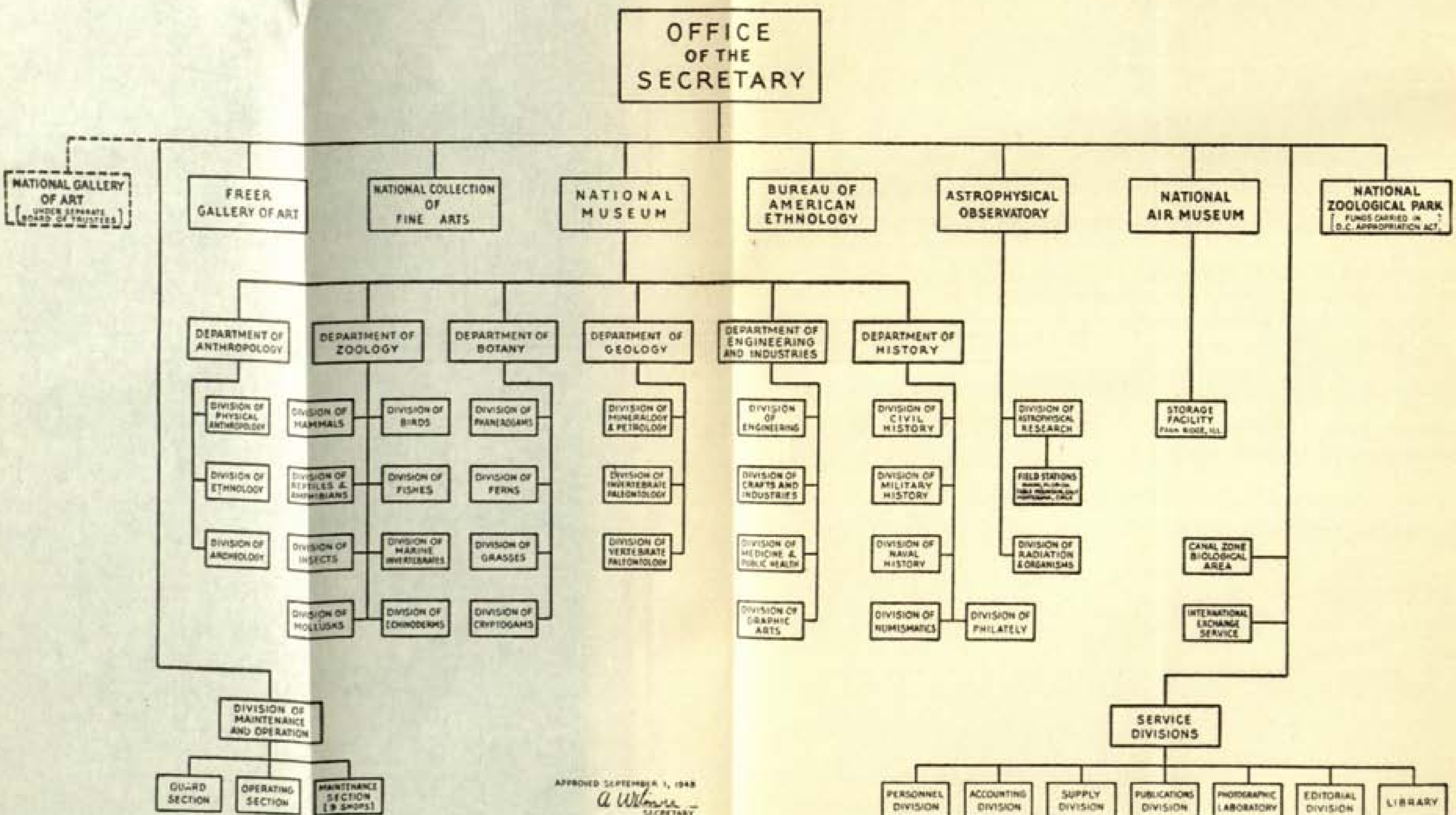
Advisory Board:
ALEXANDER WETMORE, *Chairman.*
MAJ. GEN. E. M. POWERS, *U. S. Army Air Forces.*
REAR ADM. A. M. PRIDE, *U. S. Navy.*
GROVER LOENING.
WILLIAM B. STOUT.
Assistant to the Secretary for the National Air Museum.—CARL W. MITMAN.
Curator.—P. E. GARBER.
Associate curator.—S. L. BEERS.
Exhibits preparator.—S. L. POTTER.

CANAL ZONE BIOLOGICAL AREA

Resident Manager.—JAMES ZETEK.

SMITHSONIAN INSTITUTION

ORGANIZATION CHART



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REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

ALEXANDER WETMORE

FOR THE YEAR ENDED JUNE 30, 1948

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and its bureaus during the fiscal year ended June 30, 1948.

GENERAL STATEMENT

The Institution carries out its purpose, "the increase and diffusion of knowledge among men," by numerous methods, but the basic means remain the same as those proposed by the first Secretary, Joseph Henry—namely, scientific research, exploration, and publication. These features interweave to form the pattern of activities of the Institution and of the scientific bureaus that have grown up around it and through which it now largely operates. Other features have been added as the Institution has grown and expanded—for example, museum and art gallery exhibits, which diffuse knowledge to several million visitors each year, and the International Exchange Service for the interchange of publications with the rest of the world.

In the first part of this report I present general features of the work of the Institution, together with brief summaries of the achievements of the bureaus, the whole giving a composite picture of the Smithsonian Institution in the year 1948. For those interested in further details, fuller reports on each bureau are presented as appendixes. These include the United States National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchange Service, the National Zoological Park, the Astrophysical Observatory, the National Air Museum, and the Canal Zone Biological Area. Appendixes 11 and 12 consist of reports on the Smithsonian library and on the publications of the Institution. The report concludes with the financial statement of the executive committee of the Board of Regents.

As the Institution moves into its second century of operation, it is still handicapped by certain shortages in personnel and especially by lack of adequate buildings. An institution for the increase and dif-

fusion of knowledge cannot remain static. Its scientific studies in various fields and its great and growing collections in all fields of natural history and of human endeavor demand the constant attention of an adequate staff. Laboratories and large research collections without sufficient personnel for their scientific study cannot increase knowledge. It is only as collections are correctly classified, new forms discovered and described, and groupings and relationships analyzed and reassesssed that new knowledge emerges for the benefit of mankind. For example, with an insufficient number of trained workers in various divisions of the National Museum, the actual care of the collections requires such a large proportion of the time of those now available that research is restricted. In some museum divisions, and in our other laboratories our efforts have brought about some increase of personnel, but in others the situation is still acute. Such efforts will be continued until an adequate staff for all divisions is assured.

The matter of space shortage is even more serious. The latest permanent building in the Smithsonian group—the Natural History Building of the National Museum—was opened to the public in 1911. In that year the number of visitors to the Smithsonian buildings totaled 525,207, and the total number of specimens in the National Museum was estimated at 6,328,660. For the fiscal year 1948 the number of visitors was 2,393,499—an increase of more than fourfold over 1911—and the total number of specimens reached 25,470,827—also a fourfold increase. In other words, the Smithsonian Institution has today the same amount of space that it had in 1911 in which to accommodate four times as many visitors and four times as many specimens. The inevitable result is a greatly overcrowded condition in the exhibition halls and in the study collections and laboratories, making expansion of public exhibits impossible and hampering scientific research.

The Smithsonian group of buildings is near the top of the list of Washington points of interest for visitors to the Nation's Capital from all parts of the country, and the public exhibits should be housed in modern buildings without crowding and with room for expansion as new material comes in. In the fiscal year 1946, a Public Buildings Act was introduced in Congress in which was included provision for several new Smithsonian buildings, among them a historical museum and a building for the engineering and industrial collections. The bill, however, failed of passage. In the year 1947, Congress passed a bill establishing the National Air Museum as a bureau of the Institution; this will require an adequate building. These matters are of vital concern to the proper functioning of the Institution, and the attempt to obtain adequate and up-to-date buildings will continue to be a primary concern of your Secretary.

A number of organizational changes were made during the year in

the interests of better administration, notable among them being the creation of a new department in the National Museum—that of botany, which had formerly been a division under the department of biology. The latter was thereafter known as the department of zoology. Other changes will be noted in the appended reports on the bureaus of the Institution, but I should mention here the retirement of Harry W. Dorsey, Administrative Assistant to the Secretary. Mr. Dorsey had served the Institution faithfully and well for 59 years, and his long experience in handling important matters connected with the Secretary's office and his unique knowledge of the history of the Institution will be greatly missed.

INTERDEPARTMENTAL COMMITTEE ON SCIENTIFIC RESEARCH AND DEVELOPMENT

On December 24, 1947, President Harry S. Truman established by Executive Order the Interdepartmental Committee on Scientific Research and Development, to be composed of a representative from each of the following agencies: the Departments of Agriculture, Interior, Commerce, Army, Navy, and Air Force, the National Military Establishment, the Federal Security Agency, the Atomic Energy Commission, the National Advisory Committee for Aeronautics, the Veterans Administration, and the Smithsonian Institution. In brief, the duties of the Committee are to recommend improvements in the research and development programs of the Federal Government, to recommend changes in administrative policies and procedures designed to increase the efficiency of such programs, and to study and report on current policies and practices relating to Federal support for research.

Your Secretary was appointed Chairman of the Committee by the President. An organizational meeting was held at the White House on April 16, 1948, and shortly thereafter the work of the Committee got under way. As much of this work is obviously of a confidential nature, no report on it is made at this time.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

During the year the following changes occurred in the personnel of the Board of Regents:

On January 27, 1947, Representative Clarence Cannon was reappointed a regent for another term. On July 26, 1947, Robert V. Fleming was appointed a regent by Joint Resolution, for the statutory term of 6 years, to fill the vacancy caused by the resignation of Frederic A. Delano. On November 12 Mr. Fleming was given interim appointment by the Chancellor as a member and Chairman of the Executive Committee to serve until the next meeting, when election by the Board would take place. This appointment was confirmed at the meeting of January 16, 1948.

Proceedings.—The Board of Regents held its annual meeting on January 16, 1948. Present: Representative Clarence Cannon, Dr. Vannevar Bush, Dr. Harvey N. Davis, Representative John M. Vorys, Representative Samuel K. McConnell, Jr., Robert V. Fleming, Secretary Alexander Wetmore, and Assistant Secretary John E. Graf.

The Secretary presented his annual report covering the activities of the Institution and its bureaus, including the financial report of the Executive Committee, for the fiscal year ended June 30, 1947, which was accepted by the Board. The usual resolution authorizing the expenditure by the Secretary of the income of the Institution for the fiscal year ending June 30, 1949, was adopted by the Board.

The Secretary announced a further generous gift to the Institution by John A. Roebling in support of the work of the Astrophysical Observatory.

The National Air Museum began independent operations. The aeronautical collections of the United States National Museum, numbering approximately 3,500 specimens, were transferred to the Air Museum, together with pertinent records and files. The staff of the former division of aeronautics of the National Museum, consisting of a curator and clerk-stenographer, was also transferred. Under this new set-up the Nation-wide survey for aeronautical materials continued. Arrangements were under way to take over the temporary storage at Park Ridge, Ill., where the air force had been assembling historical collections for this Museum.

The Canal Zone Biological Area on Barro Colorado Island has utilized available funds for renovation and repair. John E. Graf, Assistant Secretary, visited the laboratory in June, in connection with its administration. T. F. Clark, fiscal officer for the Institution, also visited the island in October 1947 to check over methods of accounting and inventory to insure that these meet the most recent requirements of the General Accounting Office.

The annual report of the Smithsonian Art Commission was pre-

sented by the Secretary and accepted by the Board. A resolution was adopted to reelect the following members for 4-year terms: William T. Aldrich, James Fraser, George H. Edgell, Lloyd Goodrich. The following officers were reelected for the ensuing year: Chairman, Paul Manship; vice chairman, Robert Woods Bliss; secretary, Alexander Wetmore.

Regarding the Gellatly Collection, as reported at the last annual meeting the Court of Claims in an opinion dated May 5, 1947, stated that "there is no basis in law or equity to set aside the gift or transfer and no basis in law or equity to allow a recovery in behalf of the Gellatly estate." Following this opinion, under date of May 20, 1947, the Secretary, as the custodian of the property in question, received a demand, signed by Mrs. Gellatly's attorney, to surrender possession of the collection. On June 18, 1947, a summons was served on the Secretary which was turned over to the Department of Justice. That Department assigned Marvin C. Taylor, Special Attorney, to the case, and various legal procedures have followed.

As stated in last year's report, following a decision by the Civil Service Commission, the Smithsonian trust-funds employees were included under the Federal Retirement System as of May 18, 1947. The Secretary submitted to the Executive Committee of the Board of Regents a detailed plan for carrying out the transfer, which was approved by the Committee.

FINANCES

A statement on finances, dealing particularly with Smithsonian private funds, will be found in the report of the Executive Committee of the Board of Regents, page 157.

APPROPRIATIONS

Funds appropriated to the Institution for the fiscal year ended June 30, 1948, totaled $1,800,312, allotted as follows:

General administration	$51,044
National Museum	560,548
Bureau of American Ethnology	63,352
Astrophysical Observatory	69,951
National Collection of Fine Arts	32,586
International Exchange Service	60,815
Maintenance and operation	649,352
Service divisions	267,448
National Air Museum	38,879
Canal Zone Biological Area	4,999
Unallotted	1,338
Total	1,800,312

In addition $949,426 was appropriated to the National Gallery of Art, a bureau of the Institution but administered by a separate board of trustees; and $455,400 was provided in the District of Columbia appropriation act for the operation of the National Zoological Park.

Besides these direct appropriations, the Institution received funds by transfer from other Federal Agencies, as follows:

From the State Department, from the appropriation Cooperation with the American Republics, 1948, a total of $94,882 for the operation of the Institute of Social Anthropology, including the issuance of publications resulting from its work.

From the National Park Service, Interior Department, $73,800 for archeological projects in connection with River Basin Surveys.

From the Navy Department, $11,000 for research studies on the effects of radiation upon marine life as a result of atomic bomb tests at Bikini Atoll.

VISITORS

An increase of 40,122 visitors to the Smithsonian Buildings was recorded over the previous year, the totals being 2,393,499, for 1948 and 2,353,377 for 1947. August 1947 was the month of largest attendance, with 334,578 visitors; July 1947, the second largest, with 324,815.

A summary of attendance records is given in table 1:

TABLE 1.—*Visitors to the Smithsonian Buildings during the year ended June 30, 1948*

	Smithsonian Bldg.	Arts and Industries Bldg.	Natural History Bldg.	Aircraft Bldg.	Freer Gallery of Art	Total
1947						
July	84,741	132,059	71,128	24,619	12,268	324,815
August	68,144	138,059	92,225	26,436	9,714	334,578
September	41,260	81,068	49,939	16,702	7,732	196,701
October	31,063	63,580	41,240	11,031	5,340	152,254
November	24,649	48,643	37,175	10,267	4,630	125,364
December	17,235	30,760	26,491	6,231	3,150	83,867
1948						
January	15,342	31,752	25,158	6,942	3,050	82,244
February	18,435	36,526	29,342	9,020	3,356	96,679
March	28,466	71,396	48,299	14,730	5,467	168,358
April	48,670	123,800	75,136	19,363	8,305	275,274
May	52,050	125,976	86,819	19,067	7,471	291,383
June	50,953	115,538	67,752	19,924	7,815	261,982
Total	481,008	999,157	[1] 650,704	184,332	78,298	2,393,499

[1] Not including 21,308 persons attending meetings after 4:30 p. m.

FIFTEENTH JAMES ARTHUR ANNUAL LECTURE ON THE SUN

In 1931 the Institution received a bequest from James Arthur, of New York, a part of the income from which was to be used for an annual lecture on some aspect of the study of the sun.

The fifteenth Arthur lecture, entitled "Mexican Calendars and the Solar Year," was given by Dr. Herbert J. Spinden, of the Brooklyn

Museum, on March 3, 1948, in the auditorium of the National Museum. This lecture, with illustrations, will be published in the Annual Report of the Board of Regents of the Smithsonian Institution for 1948.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—Additions to the Museum's collections numbered 507,000 specimens, coming mostly as gifts from individuals or as transfers from Government agencies. The total number of specimens in the Museum at the close of the year was 25,470,827. Among outstanding accessions for the year were: In anthropology, 2,000 archeological specimens from Cerro de las Mesas, Veracruz, collected by the National Geographic-Smithsonian Expedition, the famous Kensington stone lent by the Alexandria (Minn.) Chamber of Commerce, and casts of the famous Tepexpan skull from Mexico; in zoology, large collections of birds from Colombia, Panamá, Paraguay, and India, and valuable collections of fishes, mollusks, and marine invertebrates from the resurvey of Bikini Atoll; in botany, 5,000 specimens of fungi bequeathed by the late William H. Long, of Albuquerque, N. Mex., and 9,100 plants collected by H. A. Allard in the Dominican Republic; in geology, five meteorites not previously represented, many thousands of fossil invertebrates, including 15,000 Paleozoic and Cretaceous fossils collected by the curator of the division, and a number of outstanding fossil vertebrates including the skull and other bones of a very rare tillodont from the Bridger formation in Wyoming; in engineering and industries, a collection of 20,000 items assembled by the late Charles B. Chaney, Jr., bearing on the history of railroads, and equipment used in the first practical synchronization of sound in motion pictures; in history, a large collection from the estate of the late Victor L. Huberich including among other things 2,500 specimens of United States, Canadian, and Japanese paper money.

Field parties from the Museum's departments of anthropology, zoology, botany, and geology visited many parts of the world, including Arnhem Land in Australia, the Antarctic continent, the Bikini area in the Pacific, the Persian Gulf, Colombia, Panamá, and numerous localities in the United States. Changes in the Museum organization included the dividing of the department of biology into two departments—those of zoology and botany. The division of aeronautics was separated from the Museum to become the nucleus of the National Air Museum, a newly created bureau of the Smithsonian Institution. Dr. Remington Kellogg, formerly curator of the division of mammals, became Director of the Museum on May 26, 1948.

National Gallery of Art.—Visitors to the Gallery totaled 2,159,435 for the year, an increase of more than 700,000 over the previous year's

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figure. This large increase was due in part to the crowds attracted by the paintings from the Berlin museums, which were shown at the Gallery for more than a month in the spring of 1948. During the showing, the attendance totaled 964,970, which is believed to be a world record for museums or art galleries for a comparable period of time. Accessions to the Gallery for the year numbered 1,360, including 113 portraits presented by the A. W. Mellon Educational and Charitable Trust, 8 paintings by fifteenth- and sixteenth-century Italian and German artists presented by Mrs. Ralph Harmon Booth, and 199 additional prints and drawings given by Lessing J. Rosenwald. Nine special exhibitions were held at the Gallery, and two traveling exhibitions were circulated to art galleries and museums throughout the country. A book of illustrations on the painting and sculpture in the Widener Collection was issued, and additional fine-quality color reproductions of paintings in the Gallery were made available to the public. Many thousands attended the Gallery's special tours and lectures, and a calendar of events was mailed out to more than 3,000 persons a month. The Sunday evening concerts at the Gallery were continued with undiminished popularity, 47 such concerts being given before capacity audiences during the year.

National Collection of Fine Arts.—Ruel P. Tolman, Director, retired during the year and was succeeded by Thomas M. Beggs, Assistant Director, formerly professor of art at Pomona College, Claremont, Calif. At the annual meeting of the Smithsonian Art Commission on December 2, 1947, four oil paintings were accepted for the National Collection. Four miniatures, water color on ivory, were acquired through the Catherine Walden Myer fund. A number of art works were lent to other organizations for use in connection with special exhibitions. Six paintings were purchased from the Henry Ward Ranger fund and assigned to various art institutions. Any such purchase may be claimed by the National Collection during the 5-year period beginning 10 years after the artist's death, and two paintings by Bruce Crane were so claimed during the year. Photographic prints and post cards of art works in the National Collection are available for the public, and large numbers were sold during the year. Nine special exhibitions were held under the auspices of the National Collection of Fine Arts, for most of which catalogs were made available by the organizations holding the exhibitions.

Freer Gallery of Art.—Additions to the collections included Chinese bronze, ivory, lacquer, painting, and pottery; and Persian manuscript, painting, and pottery. The work of the professional staff was devoted to the study of new accessions and to general research within the collections of Chinese, Japanese, Arabic, Persian, and Indian materials. Reports were made upon 3,498 objects and 1,108 photographs of objects submitted for examination. The very delicate task of re-

pairing and restoring the Whistler "Peacock Room" was begun during the year. Visitors to the Gallery totaled 77,012 for the year, and 1,650 persons visited the main office for special information. Sixteen groups were given special instruction in the exhibition galleries by staff members.

Bureau of American Ethnology.—Dr. M. W. Stirling, Director of the Bureau, conducted archeological excavations in western Panamá for 3½ winter months in cooperation with the National Geographic Society, discovering a new, very early culture unrelated to anything heretofore known in the Republic. Dr. Frank H. H. Roberts, Jr., Associate Director, was occupied mainly in directing the River Basin Surveys, a unit of the Bureau set up to recover archeological material that would be lost through construction of dams and the creation of river valley reservoirs. Surveys, with limited testing of sites, were made in 18 States and 38 reservoir areas. A total of 1,576 sites have been found, of which 250 were recommended for excavation.

Dr. John P. Harrington prepared a number of manuscripts in the field of Indian linguistics, among them a 750-page grammar of the Maya language. Dr. Henry B. Collins, Jr., as chairman of the Board of Governors of the Arctic Institute of North America, devoted considerable time to the affairs of that organization. Late in the year, he left Washington to conduct archeological work for the Smithsonian and the National Museum of Canada on islands in the Canadian Arctic Archipelago. Dr. William N. Fenton carried on field work among the Seneca in western New York and started an extensive program of historical research connected with the League of the Iroquois. Dr. Philip Drucker spent nearly half the year on detail to the River Basin Surveys, taking charge of the work in the Columbia Basin. During the rest of the year he completed two monographs, one on the Nootkan tribes of British Columbia, the other on the Mexican La Venta culture. Dr. Gordon R. Willey wrote additional sections of a report on "Ancon and Supe: Formative Period Sites of the Central Peruvian Coast," and nearly completed a monograph on the archeology of the Florida Gulf Coast. Dr. Willey accompanied Dr. Stirling on the archeological expedition to western Panamá, and also worked in Tennessee for 1½ months on detail to the River Basin Surveys.

The Institute of Social Anthropology, an autonomous unit of the Bureau, is financed by State Department funds to carry out cooperative training in social anthropological teaching and research with the other American republics. Under the directorship of Dr. George M. Foster, members of the staff gave courses in various phases of anthropological study and conducted cooperative field work in Brazil, Colombia, México, and Perú. The Bureau issued volumes 3 and 4 of the Handbook of South American Indians and four publications of the Institute of Social Anthropology.

International Exchanges.—The Smithsonian International Exchange Service is the official United States agency for the interchange of governmental and scientific publications between this country and the other nations of the earth. The number of packages handled by the Service during the year was 760,119, with a total weight of 812,189 pounds. These totals represent an increase over last year of 56,321 packages and 38,214 pounds. The first shipments of exchange publications to Japan since the war were made this year. Consignments are now sent to all countries except Rumania, and negotiations are in progress for resumption of exchange relations with that country. The Exchange Service now sends abroad 94 sets of United States official publications, 73 copies of the Federal Register, and 66 copies of the Congressional Record, in return for similar material received from other nations.

National Zoological Park.—The year was a satisfactory one at the Park in that a number of unusually interesting animals were received, progress was made in recruiting personnel for the organization, and various repairs and minor improvements were made to buildings and grounds. The chief needs of the Zoo are more maintenance funds and new buildings to replace the remaining antiquated unsuitable structures built many years ago. The year's visitors reached a total of 3,040,540, an increase of more than 300,000 over the previous year's figure. The number of groups coming to the Zoo from schools was 1,454, comprising 79,249 individual students. These groups came from 27 different States, the most distant being Maine, Texas, and Wisconsin. The total number of animals in the collection at the close of the year was 2,797, representing 690 different species of mammals, birds, reptiles, and other forms. Among the exceptionally interesting animals received during the year were three species of penguins, a monkey-eating eagle, Mindanao tarsiers, and an Arctic fox.

Astrophysical Observatory.—W. H. Hoover was promoted to be Chief of the Division of Astrophysical Research. Dr. Earl S. Johnston, Chief of the Division of Radiation and Organisms, who has been responsible for the recent development of the Division, died during the year. He will be succeeded by Dr. Robert B. Withrow, of Purdue University.

The field stations at Montezuma, Chile, and Table Mountain, Calif., continued regular solar observations, and the values were checked and tabulated in Washington. The sun and sky radiation studies conducted for 2 years at Camp Lee, Va., under contract with the Office of the Quartermaster General, were terminated, but similar studies will go on at the Montezuma and Miami, Fla., stations.

During a search for the best possible site for a new high-altitude station, promising sites were located in Mexico, southern California, and the Hawaiian Islands. Instruments were installed at each of

the three sites for extended tests to determine which is the most satisfactory. A redetermination of the Smithsonian standard scale of solar radiation confirmed the Observatory's belief that the scale of a silver-disk pyrheliometer will remain unchanged for many years.

Research projects completed or well advanced during the year in the Division of Radiation and Organism included studies of the respiration of broad-leaf plants; investigations on the effects of environmental factors on the germination of seeds; and studies of the developmental physiology of grass seedlings.

The results of Observatory research appeared in nine papers published during the year.

National Air Museum.—Created as a bureau of the Smithsonian Institution in 1946, the National Air Museum did not begin actual operations in its own right until August 1, 1948, when its first appropriation of $50,000 became available. Thereupon the Institution's aeronautical collections and staff were transferred to the Air Museum, the staff was increased from two to seven persons, and separate offices were provided in the Arts and Industries Building of the National Museum. The Air Museum's Advisory Board met twice during the year and made two important decisions: 1, that there be used as a storage depot for the temporary safekeeping of Air Museum material a part of the Douglas aircraft plant built during World War II on the outskirts of Park Ridge, Ill., 20 miles from Chicago; and 2, that the Air Museum should be located in the Washington area and that the aid of the Public Buildings Administration be enlisted in designing an adequate air museum building. The Public Buildings Administration later in the year submitted a preliminary plan for a building which was approved by the Board. Numerous improvements were made to the present exhibits in the Aircraft Building, and several special exhibits were prepared during the year. A large part of the time of the curatorial staff was devoted to surveys to determine what items should be added to the aeronautical collections and what material was available throughout the country. A total of 330 objects were acquired during the year, the largest number of aeronautical acquisitions recorded in any year of the Smithsonian's history.

Canal Zone Biological Area.—This tropical laboratory on Barro Colorado Island, placed under Smithsonian administration in 1946, celebrated its twenty-fifth anniversary on April 17, 1948, and in honor of the occasion the Canal Zone issued a special commemorative 10-cent stamp. The island is maintained as a completely unspoiled tropical forest area, with laboratory facilities for investigations in biology and related subjects. Some 20 scientists from numerous universities and institutions came to the island to carry on investigations in widely varied fields, including army-ant studies, a survey of the fresh-water fishes, termite control through soil poisoning and wood treatment, the

effects of tropical conditions on photographic materials and equipment, and studies of deterioration in the Tropics of fabrics, foodstuffs, and other materials. The most urgent needs of the laboratory are a more adequate supply of electricity, an enlarged library building, and new water-storage tanks. The water-supply problem became so serious that preliminary work has already been done on the site of a new tank in the hope that the project may be completed next year.

PUBLICATIONS

The Institution's publications constitute a principal means of carrying out the "diffusion of knowledge" stipulated by the founder, James Smithson. Starting with a single series in 1848, this important phase of Smithsonian work has expanded with the growth of the Institution until today its publications appear in 14 separate series, as follows:

Smithsonian Institution: Annual Report; Miscellaneous Collections; Special Publications.
United States National Museum: Annual Report; Bulletin; Proceedings; Contributions from the National Herbarium.
Bureau of American Ethnology: Annual Report; Bulletin.
Astrophysical Observatory: Annals.
National Collection of Fine Arts: Catalog.
Freer Gallery of Art: Oriental Studies; Occasional Papers.
Institute of Social Anthropology: Publications.

These various series present the scientific findings of staff members and collaborators of the Institution, as well as of outside scientists working on its collections.

During the year, a total of 76 volumes and pamphlets were published. Among the year's outstanding publications may be mentioned a new member of the Institution's family of tables—"Smithsonian Elliptic Functions Tables," by G. W. and R. M. Spenceley; a Spanish edition of the "Compendio y descripción de las Indias Occidentales," by Antonio Vázquez de Espinosa, transcribed by Charles Upson Clark, which had been published by the Institution in English translation several years ago; "A List and Index of the Publications of the United States National Museum (1875–1946)"; volumes 3 and 4 of the "Handbook of South American Indians" (volumes 5 and 6, the last two volumes, were in press at the close of the year).

A total of 165,740 copies of publications in all series were distributed during the year. A complete list of the year's publications will be found in Appendix 12.

LIBRARY

The Smithsonian library received during the year 53,129 publications, mainly in those fields of science and art with which the Institu-

tion is concerned. Among outstanding gifts was the library of the late Charles B. Chaney, of Laurel, Md., a collection of 1,510 publications on the history of railroads. A number of rare, older books needed in connection with the Institution's researches were purchased for the library.

Volumes and pamphlets were cataloged to the number of 6,148, and 35,357 cards were added to catalogs and shelflists, but the large backlog of cataloging remained untouched for lack of sufficient personnel to do the work. A total of 10,151 publications were borrowed for use outside the library, and the library staff answered more than 15,000 reference questions. For use in aiding destroyed libraries overseas, 36,701 pieces were selected from the Smithsonian library's collection of duplicates.

The total number of volumes in the library at the close of the year was 915,987, more than half of which are housed as the Smithsonian Deposit in the Library of Congress.

Respectfully submitted.

Alexander Wetmore, *Secretary.*

[illegible] connection [illegible] with the library of the late Charles B. [illegible] [illegible] the [illegible] [illegible] in connection with the [illegible] from the library.

While [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] to the [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] from the [illegible] [illegible] of duplicates.

The total number of volumes in the library at the close of the year was [illegible], more than [illegible] of which are [illegible] in the Smithsonian Deposit in the Library of Congress.

Respectfully submitted,

[illegible]

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

Sir: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1948.

COLLECTIONS

More than 507,000 specimens were added to the Museum's collections during the year, divided among the various departments as follows: Anthropology, 16,585; zoology, 226,889; botany, 54,292; geology, 107,332; engineering and industries, 22,961; history, 79,337. Though considerably less than last year's 757,000 specimens, the total was still better than average. Most of the accessions were acquired as gifts from individuals or as transfers from Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 25,470,827.[1]

Anthropology.—The largest archeological accession consisted of more than 2,000 specimens from Cerro de las Mesas, Veracruz, collected a few years ago by a National Geographic-Smithsonian Expedition under the direction of M. W. Stirling. Nearly 500 potsherds, projectile points, and other artifacts, excavated from a Hopewellian village site near Batchtown, Ill., came as a gift. The famous Kensington stone was lent to the Museum for 6 months through the courtesy of the Alexandria (Minn.) Chamber of Commerce.

In the division of ethnology, the Far East was well represented in new material received, objects from India, Siam, Japan, and Korea being noteworthy. Interesting ethnological specimens came also from Africa, especially three fine native wood carvings. An unusually well-documented collection of Plains Indian and Apache materials included several rare pieces of special historical interest, such as the famed shield of Big Bow, a Kiowa warrior. Thirty-eight water-color paintings, illustrating the folk costumes of the peoples of Central and South America, the West Indies, and the Seminoles of Florida, were presented by the artist, Carl Folke Sablin.

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[1] Revised estimates of specimens made this year in some departments, in addition to the normal increase, have raised last year's total by nearly 6,000,000.

Among the specimens accessioned in the division of physical anthropology were four casts of the Tepexpan skull and the head of this skull as restored by the Washington sculptor Leo Steppat. Skeletal material was accessioned representing Indian sites in Calhoun, Madison, and Jersey Counties, Ill.—additions to similar material of previous years.

Zoology.—Important mammalian accessions included collections from the Arctic, Labrador and Newfoundland, Quebec and Maine, eastern Pennsylvania, Panamá, and Egypt. As in past years the W. L. Abbott fund financed wholly or in part the acquisition of several avian collections, containing a considerable number of forms new to the Museum collections and to science; of these may be mentioned 2,630 skins and 145 skeletons of Colombian birds, over 900 birdskins collected by the Smithsonian-Yale Expedition to Nepal, 835 skins and skeletons of birds from the Panamanian jungles, 237 birdskins from India, and 166 from Paraguay. Noteworthy among the reptilian material received were 1,200 specimens of burrowing snakes of the genera *Sonora* and *Tantilla* from Oklahoma and Texas; 50 Egyptian and 250 Guatemalan reptiles and amphibians; 75 reptiles from Bikini; about 50 Brazilian amphibians and 100 Peruvian reptiles and amphibians, and nearly 400 reptiles and amphibians from Virginia and North Carolina.

This year, as last, the ichthyological collections were greatly enriched by the field studies made at Bikini Atoll for the United States Navy by members of the Museum staff. More than 6,000 fishes from this region were accessioned as a result of the 1947 Bikini Scientific Resurvey. Other large fish collections included nearly 14,000 specimens from Guatemala; about 6,400 fresh-water fishes from Idaho, Nevada, California, and Arizona; and about 1,200 fishes from the Texas coast.

Several large lots of insects were received: About 22,000 miscellaneous specimens, mostly Lepidoptera, brought together by the late Elison A. Smyth, of Salem, Va.; 5,000 Far Eastern butterflies; 500 South American chalcid wasps, mostly type material; 1,500 miscellaneous insects from Liberia; an equal number from Guatemala; 4,500 from Alaska; and 77,000 transferred from the United States Bureau of Entomology and Plant Quarantine.

Much scientifically valuable material was received in the division of marine invertebrates. To the type collection of Foraminifera 836 slides were added, bringing the total now to nearly 11,500 slides. Nearly 5,000 lots of fresh-water copepods, branchiopods, ostracods, amphipods, and mysids were donated by the widow of the late S. F. Light in his memory. Similarly, Mrs. Nathaniel Gist Gee gave about 1,250 lots of fresh-water sponges. The Bikini Scientific Resurvey, of the Navy, yielded over 1,600 marine invertebrates for the Museum;

about 8,800 Pacific invertebrates came from the Naval Medical Research Unit No. 2; and about 6,000 from the Navy's Second (1948) Antarctic Development Project.

Outstanding among the year's molluscan accessions were 3,000 specimens from Cocos-Keeling Island; 9,000 from Bikini, Rongerik, and Johnston Islands, collected by members of the staff during the Bikini Scientific Resurvey; a large number from various other Pacific islands; and about 1,500 Antarctic marine mollusks. The Navy Antarctic Expedition yielded also about 500 echinoderms.

Botany.—Several unusually large plant accessions came to the National Herbarium. Among these was the bequest of 5,000 specimens of fungi, the herbarium of the late William H. Long, of Albuquerque, N. Mex. H. A. Allard collected 9,100 plants for the Museum in the Dominican Republic. An unusually interesting lot of Colombian plants came from the collector Oscar L. Haught, and collecting work of E. C. Leonard, a member of the staff, yielded 1,900 bryophytes from the Patuxent Wildlife Research Refuge, Maryland. In addition, many hundreds of desirable plant specimens and photographs were obtained by exchange or purchase.

Geology.—The general mineralogical collections continued to grow through gifts, exchanges, and purchases, and as usual the year's accessions in this field included several new species of minerals. The outstanding addition to the gem series was an Arabian stallion head carved in turquoise by Oscar J. W. Hansen. Five meteorites not previously represented in the department's collections were received by gift, and excellent additions to the ore collections came from many sources. Rock specimens received contained important described material.

Many important specimens of fossil invertebrates came to the Museum as gifts, four of the larger lots being 2,000 Ordovician fossils from Minnesota; 1,700 Mesozoic and Tertiary fossils from Cuba; 15,000 Devonian and Upper Paleozoic fossils from Nevada; and 1,700 Jurassic brachiopods and mollusks from the vicinity of the Smithsonian's Astrophysical Observatory station at Calama, Chile, collected by Miss Jessie G. Beach, of the department staff, while on vacation. Through the Walcott funds there were received 900 specimens of various invertebrates from the famous Permian deposits of Sosio Valley, Sicily; 2,500 from the Devonian of Ontario; 50,000 Paleozoic fossils collected by Dr. A. R. Loeblich, Jr., of the staff; and 15,000 Middle-Upper Paleozoic and Cretaceous fossils collected by Curator G. A. Cooper and Elias Yochelson. Several large transfers of specimens came from the United States Geological Survey.

This was a banner year for the division of vertebrate paleontology, the greatest number of specimens being added to the collections since the field season of 1931. The outstanding acquisition was the skull,

jaws, and a foot of the tillodont *Trogosus castoridens* from the Bridger formation near Church Buttes, Wyo., the second skull of this rare mammal to be found during intermittent exploration covering 75 years. Equally significant was the discovery of the rostral portion of the skull of *Esthonyx acutidens*, an earlier member of the tillodont order from the Wind River beds of Wyoming. This specimen, found by H. A. Tourtelot, was transferred from the United States Geological Survey. Exceptionally valuable for exhibition purposes was the large slab of giant amphibian skulls and other skeletal parts representing the Triassic form *Buettneria perfecta*, secured by the associate curator's party near Lamy, N. Mex. Other specimens that came as a result of the division's field work were two well-preserved skulls of the Eocene primate *Notharctus;* additional specimens of *Trogosus*, of the rhino *Hyrachyus*, and the tapir *Helaletes;* and skulls of the small rodents *Mysops* and *Sciuravus*. Jurassic fishes collected by the associate curator represent some of the earliest bony fishes and are important in providing unusual specimens for growth studies.

Engineering and industries.—An outstanding accession in the division of engineering was the collection of railroad historical material assembled by the late Charles B. Chaney, Jr., totaling about 20,000 items. Another railroad accession was a group of models showing the evolution of the equipment of The Empire State Express, the New York Central famous train. Various commercial firms continued their cooperation by contributing material relating to industrial products and manufactures, and interesting electrical items came from a number of sources. Through the Dahlgreen fund 15 fine original prints of historical and technical importance were added to the graphic arts collections; included in the group are prints by Breughel, Goya, Delacroix, Blake, Daumier, Rodin, and Zorn. Among the photographic material received was equipment used in the first practical synchronization of sound in motion pictures. An interesting accession in the division of medicine and public health was one of the first of the so-called "drunkometer" instruments now used extensively by police departments to determine the amount of alcohol in the breath and tissues.

History.—A notable acquisition in this division was a large numismatic and philatelic collection from the estate of the late Victor L. Huberich, consisting of more than 2,500 specimens of United States, Canadian, and Japanese paper money and about 73,000 Mexican revenue stamps and Japanese postage stamps. This is a collection of unusual historical interest and is the first important addition to the Museum's collection of United States paper currency in many years. The numismatic series were increased also by the addition of 72 commemorative medals lent by the Bureau of the Mint. The most important addition to the costumes collection was a green silk, flow-

ered, brocade wedding dress, worn by Sarah Pierpont who married Jonathan Edwards in 1727. The military and naval collections were enhanced by a number of interesting objects, one lot of special importance being a collection of 72 Teacher Type ship models of the sort used by the Navy for training during World War II and 10 wooden display cases for them.

EXPLORATION AND FIELD WORK

Field work by members of the staff of the departments of anthropology, zoology, botany, and geology was continued during the year as opportunities offered.

In January four Museum staff members—Frank M. Setzler, head curator of anthropology, and biologists David H. Johnson, Herbert G. Deignan, and Robert R. Miller—left for Australia to participate in an anthropological and biological survey of little-known Arnhem Land sponsored by the Smithsonian Institution, the Australian Commonwealth, and the National Geographic Society. This expedition was still in the field at the close of the fiscal year, but had already reported good progress in its studies and collections.

Early in the year the associate curator of ethnology, John C. Ewers, spent nearly 3 months on the Blackfeet Reservation in Montana and the Blood Reserve in Alberta interviewing aged Indians on traditional arts and crafts and on the role of the horse in Blackfoot culture. Briefer periods were spent on the Flathead Reservation in Montana and the Pine Ridge Reservation in South Dakota obtaining comparative materials on Flathead and Oglala Sioux horse culture.

Dr. Waldo R. Wedel, associate curator of archeology, was detailed during most of the year to the River Basin Surveys under the Bureau of American Ethnology and spent considerable time in the field, particularly in the Missouri River Basin. (See appendix 5 for details.)

The Smithsonian took part in the Navy's Second (1948) Antarctic Development Project, and Commander David C. Nutt was employed as biologist on a temporary basis to represent the Museum. The result was the collecting of one of the best representations of Antarctic marine life, particularly invertebrates, ever to accrue to the national collections. Charles O. Handley, Jr., likewise temporarily employed, accompanied a naval expedition to the American Arctic Archipelago, where he secured a fine lot of Arctic birds and mammals for the Museum.

During the first 2 months of the year Dr. Leonard P. Schultz, curator of fishes, Dr. J. P. E. Morrison, associate curator of mollusks, and Frederick M. Bayer, assistant curator of marine invertebrates, participated in the Bikini Scientific Resurvey organized by the Department of the Navy, the United States Armed Forces Special Weap-

ons Project, and the Atomic Energy Commission. This investigation was made for the purpose of determining the possible long-range effects of the Operation Crossroads atom-bomb experiments on the animal and plant life of the area. Extensive collections were made, with emphasis on fishes and marine invertebrates.

Donald S. Erdman, biological aid in the division of fishes, left on March 21 to make a survey of the fishery resources of the Persian Gulf.

Other zoological field projects participated in by the Museum included the following: A survey of the small mammals of eastern Pennsylvania and their ectoparasites, sponsored by the United States Public Health Service; a similar survey at Air Transport Command bases in Greenland, Labrador, Newfoundland, Quebec, and Maine, in cooperation with the Army Medical Center; two ornithological expeditions financed by the W. L. Abbott fund, one in Colombia and one in Panamá; alcyonarian studies in southern Florida; a survey of Lithia Spring, Fla., following the reported occurrence there of an Asiatic snail known as the intermediate host of the disease paragonimiasis of the western Pacific.

No formal expeditions were participated in by the department of botany during the year, but various members of the staff did collecting work in eastern Canada, Maryland, and southern Oregon and northern California. Dr. F. A. McClure, research associate, was in Central America from December to June, continuing field studies of American bamboos.

In the department of geology, field work again yielded interesting and needed study specimens of fossils. Dr. G. A. Cooper, curator of invertebrate paleontology, and party collected Devonian and Mississippian fossils in the region of Alamogordo, the San Andres Mountains, and Silver City, N. Mex., and later Permian fossils in the Glass Mountains, Tex., and Lower and Middle Ordovician material in the Arbuckle Mountains and Criner Hills, Okla. Associate Curator A. R. Loeblich's field work took him to western New York and Ontario, where he collected from Middle Devonian deposits; to Sylvania, Ohio, where he obtained more Devonian invertebrate fossils; to Illinois (Pennsylvanian rocks) and eastern Missouri (Silurian); and to Tennessee, where he collected Ordovician and Silurian fossils in the Central Basin and also visited important Silurian and Devonian localities in the western part of the State.

Dr. C. Lewis Gazin, curator of vertebrate paleontology, resumed his program of mammalian collecting in the Middle Eocene Bridger formation, Wyoming, and obtained outstanding primate, creodont, insectivore, perissodactyl, and rodent material, as well as some good reptile skulls.

Under the leadership of Dr. David H. Dunkle, associate curator

of vertebrate paleontology, a field party spent several weeks at a Triassic rock quarry near Lemy, N. Mex., recovering 19 blocks of the bone-bed material. Composed primarily of the dissociated remains of the giant stereospondylous amphibian *Buettneria*, the collection includes at least 35 skulls of this animal, as well as a multitude of other skeletal parts. Dr. Dunkle also made a search for fossil fishes in the Jurassic beds east of Santa Rosa, N. Mex., and his party obtained 87 specimens representing two genera of primative teleosts. Prior to the close of the year Dr. Dunkle and A. C. Murray undertook field work in the marine Pierre Shale north of Lusk, eastern Wyoming.

PUBLICATIONS

Twenty-four Museum publications were issued during the year: 1 Annual Report, 4 Bulletins, 17 Proceedings papers, and 2 papers in the Bulletin series, Contributions from the United States National Herbarium. A list of these is given in the complete report on Smithsonian publications, appendix 12. Special mention should be made of Bulletin 193, published in December 1947, comprising a list and index of all the publications of the United States National Museum from 1875, when the first Museum Bulletin was issued, until the end of 1946. It is the first such list and index to be published in more than 40 years. It was compiled in the editorial division.

The distribution of volumes and separates to libraries and other institutions and to individuals aggregated 50,970.

CHANGES IN ORGANIZATION

A number of important changes in the Museum organization were effected during the year.

On July 31, 1947, the department of biology was divided into two departments—zoology and botany—the former division of plants (the National Herbarium) being raised to the status of a full department. Ellsworth P. Killip was named head curator of the department of botany, while Dr. Waldo L. Schmitt continued as head curator of zoology. Three divisions were created in the new department—phanerogams, grasses, and cryptogams—and toward the close of the year a fourth one, the division of ferns, was established, to become effective on July 1, 1948.

The division of aeronautics was separated from the department of engineering and industries on July 31, 1947, to become the nucleus of the National Air Museum, established by Congress in 1946 as a bureau of the Smithsonian Institution. This change took from the department Paul E. Garber, curator of aeronautics, with 28 years of service in the Museum, to become curator of the National Air Museum.

On March 7, 1948, Carl W. Mitman, head curator of the department of engineering and industries since 1932, left the staff of the National Museum to become Assistant to the Secretary for the National Air Museum. Frank A. Taylor, curator of engineering, was appointed head curator of the department on May 3, 1948.

During the year Dr. Alexander Wetmore, who since 1945 had been serving in the double capacity as Secretary of the Smithsonian Institution and also as Director of the National Museum, relinquished the latter position. Dr. Wetmore had been in charge of the Museum since 1925. On May 26, 1948, Dr. Remington Kellogg, curator of the division of mammals, was appointed as the new Director.

Respectfully submitted.

REMINGTON KELLOGG, *Director*.

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees, the eleventh annual report of the National Gallery of Art, for the fiscal year ended June 30, 1948. This report is made pursuant to the provisions of section 5 (d) of Public Resolution No. 14, Seventy-fifth Congress, first session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. The five general trustees continuing in office during the fiscal year ended June 30, 1948, were Samuel H. Kress, Ferdinand Lammot Belin, Duncan Phillips, Chester Dale, and Paul Mellon. The Board of Trustees held its annual meeting on May 4, 1948. Samuel H. Kress was reelected President and Ferdinand Lammot Belin Vice President, to serve for the ensuing year. Donald D. Shepard continued to serve during the year as Advisor to the Board.

All the executive officers of the Gallery continued in office during the year:

Huntington Cairns, Secretary-Treasurer.
David E. Finley, Director.
Harry A. McBride, Administrator.
Huntington Cairns, General Counsel.
John Walker, Chief Curator.
Macgill James, Assistant Director.

The three standing committees of the Board, as constituted at the annual meeting May 4, 1948, were as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, ex officio, Fred M. Vinson, Chairman.
Samuel H. Kress, Vice Chairman.
Ferdinand Lammot Belin.
Secretary of the Smithsonian Institution, Dr. Alexander Wetmore.
Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, ex officio, John W. Snyder, Chairman.
Samuel H. Kress, Vice Chairman.

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Ferdinand Lammot Belin.
Chester Dale.
Paul Mellon.

ACQUISITIONS COMMITTEE

Samuel H. Kress, Chairman.
Ferdinand Lammot Belin, Vice Chairman.
Duncan Phillips.
Chester Dale.
David E. Finley, ex officio.

Lamont Moore, curator in charge of education, resigned on August 31, 1947, to accept the position of Assistant Director of the American Academy in Rome. On March 25, 1948, Dr. Raymond S. Stites was appointed curator in charge of education.

On June 30, 1948, the Government employees on the staff of the National Gallery of Art totaled 312, as compared with 305 employees as of June 30, 1947. The United States Civil Service regulations govern the appointment of employees paid from appropriated public funds.

Throughout the year a high standard of operation has been maintained in all departments of the Gallery. The entire staff was especially commended by the Board of Trustees for outstanding service during the exhibition of paintings from the Berlin museums, which brought unprecedented numbers of visitors to the Gallery.

APPROPRIATIONS

For the fiscal year ended June 30, 1948, the Congress of the United States appropriated for the National Gallery of Art the sum of $949,426 to be used for salaries and expenses in the operation and upkeep of the Gallery, the protection and care of works of art, and administrative and other expenses.

From this appropriation the following expenditures and encumbrances were incurred:

Personal services	$816,880.00
Printing and binding	6,181.46
Supplies, equipment, etc	126,319.16
Unencumbered balance	45.38
Total	949,426.00

In addition to this appropriation, the Gallery received from the Department of State the sum of $5,800 to cover expenses during the fiscal year of the Inter-American Office, in closing out the Gallery's participation in the program of exchange of art and art materials between the United States and other American republics. Of this sum, $5,327.06 was expended, primarily in the circulation of eight exhibitions and the subsequent return of loaned objects. The unobligated balance was $472.94.

ATTENDANCE

There were 2,159,435 visitors to the Gallery during the fiscal year, an average daily attendance of about 5,932. This was an increase of 711,397 over the total of 1,448,038 visitors in the previous fiscal year. During the period between March 17, 1948, and April 25, 1948, when the paintings from the Berlin museums were on exhibition, a total of 964,970 people visited the Gallery. On one day, April 11, 1948, the Gallery attendance set an all-time high of 67,490.

ACCESSIONS

There were 1,360 accessions by the National Gallery of Art, as gifts, loans or deposits, during the fiscal year. Most of the paintings and a number of the prints were placed on exhibition.

PAINTINGS

A special opening was held February 1, 1948, to exhibit recent additions to the Ralph and Mary Booth Collection, consisting of eight paintings by Italian and German artists of the fifteenth and sixteenth centuries. These paintings were presented to the Gallery by Mrs. Ralph Harman Booth, of Detroit, and their acceptance was confirmed by the Board of Trustees on October 13, 1947. Also exhibited at the same time were previous donations to the same collection. A special catalog was prepared for the opening. The paintings received were:

Artist	*Title*
Boltraffio	Portrait of a Youth.
Bellini	Madonna and Child.
Tintoretto	Madonna of the Stars.
Cranach, Lucas, the Elder	A Prince of Saxony.
Cranach, Lucas, the Elder	A Princess of Saxony.
Strigel	The Mayor of Memmingen.
Strigel	The Wife of the Mayor of Memmingen.
Kremer	Portrait of a Nobleman.

The A. W. Mellon Educational and Charitable Trust presented to the Gallery 113 portraits, which were accepted by the Board on December 22, 1947. The gift contains a provision for the transfer of portraits, in certain circumstances, to a National Portrait Gallery, when and if established. The paintings are as follows:

Artist	*Title*
John Hesselius	Thomas Johnson.
Rembrandt Peale	George Washington (after Pine).
Douglas Volk	Abraham Lincoln.
John James Audubon (?)	Portrait of a Girl.
Asher B. Durand	Gouverneur Kemble.
Jacob Eichholtz	William Clark Frazer.
Jacob Eichholtz	James P. Smith.
Charles Loring Elliott	Self-Portrait.

Artist	Title
Charles Loring Elliott	William S. Mount.
Daniel Huntington	Henry Theodore Tuckerman.
Henry Inman	George Pope Morris.
William S. Mount	Charles Loring Elliott.
Charles Willson Peale	Timothy Matlack.
Thomas Sully	Robert Walsh.
Jeremiah Theus	Isaac Motte.
John Trumbull	William Rogers.
John Vanderlyn	John Sudam.
Francis Alexander	Sarah Blake Sturgis.
Washington Allston	Stuart's Family.
Ezra Ames	Maria Gansevoort Melville.
Joseph A. Ames	George Southward.
Joseph Badger	Judge Robert Auchmuty, Sr.
Henry Benbridge	Oliver de Lancey.
Joseph Blackburn	General Joshua Winslow.
Charles Bridges	William Gooch.
Charles Bridges	Anne Brown Hamilton.
Mather Brown	Thomas Dawson.
Mather Brown	Alexander Hamilton.
Alvan Clark	Barnabus Clark.
James Claypoole	Margaret Hamilton Allen.
John Singleton Copley	Jeremiah Taylor.
Henri Couturier	Frederick Philipse.
Henri Couturier	Oloff Stevense van Cortlandt.
Abraham Delanoy	Peter R. Livingston.
William Dunlap	John Howard Payne.
Asher Brown Durand	Christian Gobrecht.
Evert Duyckinck, 1st	Stephanus van Cortlandt.
Evert Duyckinck, 3rd	Ann Sinclair Crommelin.
Gerardus Duyckinck	James de Lancey.
Gerret Duyckinck	Anne van Cortlandt.
Ralph E. W. Earl	Thomas Earl.
Ralph E. W. Earl	Samuel Stanhope Smith.
Jacob Eichholtz	Mrs. Phoebe Freeman.
Nathaniel Emmons	Jonathan Belcher.
Robert Feke	Ruth Cunningham.
Robert Feke	Foster Hutchinson.
James Frothingham	Ebenezer Newhall.
Robert Fulton	Mahlon Dickerson.
Robert Fulton	Henry Eckford.
Robert Fulton	Marion (Bedell) Eckford and Henrietta Eckford.
Chester Harding	Chester Harding.
James Herring	William Augustus Conway.
Daniel Huntington	James Hall.
Daniel Huntington	John Edwards Holbrook.
Henry Inman	Clara Barton.
Henry Inman	Charles Fenno Hoffman.
Henry Inman	Mrs. Elizabeth Oakes Smith.
John Wesley Jarvis	James Lawrence.
David Johnson	Edwin Forrest.
Eastman Johnson	Joseph Wesley Harper.

Artist	*Title*
Henrietta Johnston	Robert Johnson.
John Johnston	John Peck.
Charles Bird King	Grace Greenwood.
Thomas B. Lawson	William Morris Hunt.
Edward G. Malbone	Margaret Maria Livingston.
Edward D. Marchant	Charles Fenno Hoffman.
John Mare	Robert Monckton.
Eliab Metcalfe	Alexander Anderson.
Samuel F. B. Morse	Coralie Livingston Barton.
Samuel F. B. Morse	Katherine Augusta Rhodes Ware.
John Neagle	John Davis.
John Neagle	Mrs. John Dickson.
John Neagle	Thomas W. Dyott.
John Neagle	Ann C. Rudman.
John Neagle	William C. Rudman.
John Neagle	John Albert Ryan.
John Neagle	Miss Ryan.
James Peale	General Mordecai Gist.
Rembrandt Peale	Peter B. Porter.
Rembrandt Peale	Richardson Stuart.
Peter Pelham	Jonathan Law.
Peter Pelham	John Smibert.
Robert Edge Pine	General William Smallwood.
Matthew Pratt	John Cochran.
William Read	Richard Bellingham.
John Smibert	Stephen de Lancey.
John Smibert	Alexander Garden.
John Smibert	Governor William Shirley.
John Smibert	Susannah de Lancey Warren.
F. R. Spencer	Frances Ludlum Morris.
Junius Brutus Stearns	Charles Gamage Eastman.
J. G. Strycker	Jan Strycker.
J. G. Strycker	Adrian van der Donck.
Gilbert Stuart	Sir Francis N. P. Conyngham.
Gilbert Stuart	Cyrus Griffin.
Gilbert Stuart	James Lloyd.
Gilbert Stuart	Mrs. Andrew Dexter.
Thomas Sully	Thomas Alston.
Thomas Sully	Dr. William Gibson.
Thomas Sully	Julianna Hazelhurst.
Thomas Sully	John Philip Kemble (after Stuart).
Jeremiah Theus	Josias Allston.
Jeremiah Theus	Johann deKalb.
Edward Truman	Jonathan Sewell.
John Vanderlyn	Miss Robinson.
Pieter Vanderlyn	Johannes van Vechten.
John Watson	Sir Peter Warren.
Adolph U. Wertmüller	Philip van Cortlandt.
Benjamin West	Elizabeth Beckford.
Benjamin West	Elizabeth Gordon.
John Wollaston	Captain Archibald Kennedy.
John Wollaston	John Stevens.
James R. Lambdin	Abraham Lincoln.

Cornelius Vanderbilt Whitney's gift of a Van Dyck portrait of Henri II de Lorraine, Duc de Guise, was accepted on the same date.

Three paintings given by William C. Freeman were accepted by the Board of Trustees on October 13, 1947. One was a group portrait, "The Coleman Sisters, Isabel, Sarah, and Margaret," by Thomas Sully. The others were portraits of Mr. and Mrs. Robert Coleman, by Rembrandt Peale. At the same time a painting given by Stephen C. Clark, entitled "Hound and Hunter," by Winslow Homer, was accepted. On December 22, 1947, the Board accepted from Mrs. Gordon Dexter an oil sketch entitled "The Death of Lord Chatham," by John Singleton Copley. A portrait of George Washington, by Charles Peale Polk, was accepted from William C. Freeman on the same date, to be held for a National Portrait Gallery. On March 1, 1948, the Board of Trustees accepted from Mrs. Henry R. Rea a portrait, attributed to the English School, of the Earl of Essex, and from Mrs. Augustus Vincent Tack a portrait of her mother, Mrs. George Fuller, by George Fuller. On June 16, 1948, the Board accepted from Oscar Doyle Johnson a painting entitled "Catherine," by Robert Henri.

PRINTS AND DRAWINGS

A gift from Lessing J. Rosenwald of 199 additional prints and drawings was accepted on October 13, 1947, to be added to the Lessing J. Rosenwald Collection. At the same time, six prints and drawings were accepted from Myron A. Hofer. On May 4, 1948, the Board accepted from Mrs. Josephine Bradlee, Mrs. Percy D. Morgan, and Caspar C. de Gersdorff a total of 270 prints and drawings by Segonzac, and 42 illustrated books, given in memory of the late Frank Crowninshield.

During the year the Board accepted from Chester Dale a drawing and an etching, two prints from David Keppel, and a woodcut from an anonymous donor. The offer of Lessing J. Rosenwald to exchange an engraving by Aldegrever for a better impression was also accepted.

SCULPTURE

On October 13, 1947, the Board accepted from Eames MacVeagh a bronze portrait medallion of Wayne MacVeagh, by Augustus Saint-Gaudens, to be held for a National Portrait Gallery.

WORKS OF ART ON LOAN

During the fiscal year 1948 the following works of art were received on loan by the National Gallery of Art:

From	*Artist*
Anonymous loan:	
Paradise Valley	John La Farge.
Mrs. Charles Carstairs, Paris, France:	
Colonel Pocklington and His Sisters	George Stubbs.

From	*Artist*
Richard W. Norton, Shreveport, La.:	
Result of the Election	George Caleb Bingham.
George Matthew Adams, New York, N. Y.:	
Memory Copy of Holbein's Erasmus	Alphonse Legros.
244 prints	Alphonse Legros.
Robert Woods Bliss, Washington, D. C.:	
30 objects of Pre-Columbian Art.	

LOANED WORKS OF ART RETURNED

The following works of art on loan were returned during the fiscal year 1948:

To	*Artist*
Mme. Charlotte Fuerstenberg, New York, N. Y.:	
Walk at Chantilly	Cezanne.
The Skating Rink	Manet.
Albert Wolfe	Manet.
Reinhold Hans Cassirer, New York, N. Y.:	
At the Piano	Renoir.
Mrs. Huttleston Rogers, New York, N. Y.:	
The Tricycle	Monet.
Sarah Bernhardt as Fedora	Stevens.
The J. H. Whittemore Company, Naugatuck, Conn.:	
Behind the Scenes—Ballet Girls	Degas.
Still Life—Apples and Sugar Bowl	Renoir.
Landscape	Ryder.
Flower Shop, Dieppe	Whistler.
Street at Bourges	Whistler.
Venice—The Doorway	Whistler.
The Dancers	Degas.
Two Studies of Mary Cassatt at the Louvre	Degas.
Ballet Dancer Fixing Her Slipper	Degas.
Ballet Dancer Leaning Forward	Degas.
Nude Figure Leaning Forward and Holding Right Foot	Degas.
Islets on the Seine at Port Villers, 1883	Monet.
The Sea	Whistler.
James Hazen Hyde, New York, N. Y.:	
4 tapestries.	
Chester Dale, New York, N. Y.:	
24 prints	Various.

WORKS OF ART LOANED

During the fiscal year 1948, the Gallery loaned the following works of art for exhibition purposes:

To	*Artist*
The Virginia Museum of Fine Arts, Richmond, Va.:	
Benjamin Harrison	Charles Willson Peale.
The Saginaw Museum, Saginaw, Mich.:	
John Randolph	Gilbert Stuart.
The Denver Art Museum, Denver, Colo.:	
Alexander Hamilton	John Trumbull.
The United States Supreme Court, Washington, D. C.:	
Thomas Johnson (?)	John Hesselius (?).

To	*Artist*
The White House, Washington, D. C.:	
George Washington	Rembrandt Peale (after Pine).
Franklin Pierce	G. P. A. Healy.
James Monroe	John Vanderlyn.
The Whitney Museum of American Art, New York, N. Y.:	
Siegfried and the Rhine Maidens	Albert P. Ryder.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year ended June 30, 1948:

Chiaroscuro Woodcuts from the Sixteenth through the Eighteenth Centuries. Loaned anonymously. Continued from previous fiscal year. June 8 to November 16, 1947.

Etchings of James McNeill Whistler. Exhibition from the gift of Mr. and Mrs. J. Watson Webb, New York, N. Y. Continued from previous fiscal year. June 13 to October 24, 1947.

Prints by Henri de Toulouse-Lautrec. Exhibition of prints from the Rosenwald Collection. October 25, 1947, to April 4, 1948.

Men of Action of the Naval Services, World War II. A group of war portraits of personnel of the naval services, for eventual installation in the proposed National Museum of Military and Naval History. November 23 to December 14, 1947.

The Art of France in Prints and Books. Exhibition of prints and books from the Rosenwald and Widener Collections; also books from the Rosenwald Collection in the Library of Congress. December 12, 1947, to March 4, 1948.

Paintings from the Berlin Museums. Exhibition of paintings brought to this country for safekeeping by the Department of the Army and stored at the National Gallery of Art. Exhibited at the request of the Department of the Army. March 17 to April 25, 1948.

Prints by James McNeill Whistler. Exhibition of prints from the Rosenwald Collection; one print from the Hofer Collection. Opened April 6, 1948.

American Paintings from the Collection of the National Gallery of Art. Exhibition of American paintings, featuring a group of portraits from Pocahontas to General Eisenhower. Opened May 23, 1948.

Indigenous Art of the Americas, from the Robert Woods Bliss Collection. Continued from the previous year with rearrangements and additions made by Mr. Bliss this year. Reopened with changes, May 23, 1948.

TRAVELING EXHIBITIONS

Rosenwald Collection.—During the fiscal year 1948 special exhibitions of prints from the Rosenwald Collection were circulated to the following:

Los Angeles County Museum, Los Angeles, Calif.:
  Rembrandt Exhibition, 50 etchings, 5 drawings.
    November 18 to December 31, 1947.
Grand Rapids Art Gallery, Grand Rapids, Mich.:
  Six Centuries of Prints, 80 prints.
    December, 1947.

The Art Alliance, Philadelphia, Pa.:
Contemporary Print Making in France, 8 prints.
February 2 to March 1, 1948.
Philadelphia Museum of Art, Philadelphia, Pa.:
Collector's Choice, 5 prints.
February 7 to March 14, 1948.
J. B. Speed Museum, Louisville, Ky.:
"Great Passion" Woodcuts, 21 Dürer woodcuts.
March 6 to March 28, 1948.
Worcester Art Museum, Worcester, Mass.:
50th Anniversary Exhibition, 22 prints.
April 7 to May 15, 1948.

Index of American Design.—Exhibitions from this collection were shown during the fiscal year 1948 at the following places: Ohio State Museum, Columbus, Ohio; N. W. Ayer Gallery, Philadelphia, Pa.; Library of Congress, Washington, D. C.; M. H. De Young Memorial Museum, San Francisco, Calif.; Pomona College, Claremont, Calif.; Santa Barbara Museum of Art, Santa Barbara, Calif.; Los Angeles Public Library, Los Angeles, Calif.; Pasadena Art Institute, Pasadena, Calif.; Pfeiffer College, Misenheimer, N. C.; Schenectady Museum, Schenectady, N. Y.; Long Beach Art Association, Long Beach, Calif.; Children's Museum, Denver Art Museum, Denver, Colo.; Honolulu Academy of Art, Honolulu, Hawaii; Winter Industries Cooperative, Northeast Harbor, Me.; Children's Museum, Irvington-on-Hudson, N. Y.; West Virginia Institute of Technology, Montgomery, W. Va.; San Joaquin Pioneer Museum, Stockton, Calif.; Western Reserve Historical Society, Cleveland, Ohio; Jewish Community Center, Washington, D. C.; Smithfield High School, Smithfield, Va.; Norfolk Museum of Arts and Sciences, Norfolk, Va.; University of Oregon, Eugene, Oreg.; Albion College, Albion, Mich.; Washington County Museum of Fine Arts, Hagerstown, Md.; Joslyn Memorial Art Gallery, Omaha, Nebr.; New York State Historical Association, Cooperstown, N. Y.; Shaker Work Camp, Mt. Lebanon, N. Y.

PAINTINGS FROM THE BERLIN MUSEUMS

On March 6, 1948, it was announced that the National Gallery of Art, at the request of the Department of the Army, would place on exhibition from March 17 to April 18, 1948, the 202 paintings from the Berlin museums which were brought to the United States in 1945 for safekeeping, and which had been stored since that time in the National Gallery of Art. Shown during the Gallery's regular exhibition hours, the paintings attracted widespread public interest, and were viewed by such large numbers of visitors that new attendance records were established. The exhibition was extended for one week to April 25, and the total attendance reached an all-time high of 964,970 visitors, which is believed to be a record for any museum or

art gallery in the world in a comparable period. Following the close of the exhibition, the custody of the paintings passed from the National Gallery of Art to the Department of the Army.

In accordance with the expressed wishes of the Senate Armed Services Committee and the Department of the Army, a meeting of museum and gallery officials was held at the National Gallery of Art on April 29, 1948, to prepare plans for an exhibition tour of certain of these paintings. Attending the meeting were: David E. Finley, Director, National Gallery of Art, presiding; G. H. Edgell, Director, Museum of Fine Arts, Boston, Mass.; H. F. Jayne, Vice Director, and Dudley T. Easby, Secretary, Metropolitan Museum of Art, New York, N. Y.; Fiske Kimball, Director, Philadelphia Museum of Art, Philadelphia, Pa.; Homer Saint-Gaudens, Director, Department of Fine Arts, Carnegie Institute, Pittsburgh, Pa.; Daniel Catton Rich, Director, Art Institute of Chicago, Chicago, Ill.; William M. Milliken, Director, Cleveland Museum of Art, Cleveland, O.; Edgar P. Richardson, Director, Detroit Institute of Arts, Detroit, Mich.; Edward S. King, Acting Administrator, and David Rosen, Technical Advisor for Preservation and Restoration, Walters Gallery, Baltimore, Md.; Blake-More Godwin, Director, Toledo Museum of Art, Toledo, O.; Russell A. Plimpton, Director, Minneapolis Institute of Arts, Minneapolis, Minn.; James W. Foster, Jr., Baltimore Museum of Art, Baltimore, Md.; also present were: Col. T. Scott Riggs and Maj. Gerard B. Crook, General Staff Corps, Civil Affairs Division, United States Army, and Abraham J. Harris, Department of Justice.

At this meeting a proposed schedule of exhibitions throughout the United States was agreed upon, and subsequently confirmed with amendments by the Department of the Army.

In conformity with instructions from the Department of the Army, 52 of the paintings which were considered most likely to suffer damage or deterioration if sent on an exhibition tour were packed for immediate shipment back to the American Zone in Germany. These paintings were chosen by the following committee, which met at the National Gallery of Art on April 27, 1948: John Walker, Chairman, Chief Curator, National Gallery of Art; Daniel Catton Rich, Director of the Chicago Art Institute; George Stout, Director of the Worcester Art Museum; Stephen S. Pichetto, Consultant Restorer to the National Gallery of Art and to the Metropolitan Museum of Art; and Dr. Irene Kuehnel, formerly Curator of Paintings of the Kaiser Friedrich Museum and currently attached to Military Government in the American Zone, Germany.

The remainder of the paintings were packed and sent on tour in accordance with plans approved by the Department of the Army. At the Department's request, the National Gallery of Art agreed to supervise technical and professional details involved in sending the

paintings on an exhibition tour. The following institutions were scheduled to participate in the tour:

Metropolitan Museum of Art, New York, N. Y.
Philadelphia Museum of Art, Philadelphia, Pa.
Art Institute of Chicago, Chicago, Ill.
Museum of Fine Arts, Boston, Mass.
Detroit Institute of Arts, Detroit, Mich.
Cleveland Museum of Art, Cleveland, Ohio.
Minneapolis Institute of Arts, Minneapolis, Minn.
M. H. De Young Memorial Museum, San Francisco, Calif.
Los Angeles County Museum of History, Science and Art, Los Angeles, Calif.
City Art Museum of St. Louis, St. Louis, Mo.
Carnegie Institute, Pittsburgh, Pa.
Toledo Museum of Art, Toledo, Ohio.

CURATORIAL ACTIVITIES

The Curatorial Department accessioned 1,360 new gifts to the Gallery during the year. Advice was given in the case of 205 works of art brought to the Gallery for opinion, and 21 visits were made in connection with proffered works of art. More than 500 research problems were investigated in response to inquiries received by the Gallery. During the year 16 lectures and 4 lecture courses were given by members of the curatorial staff. Charles Seymour, Jr., gave a series of lectures on Renaissance art at the Johns Hopkins University, and carried on special research in Europe in connection with the Gallery's sculpture collection.

Changes were made in the installation of the Bliss Collection of Pre-Columbian Art, to accommodate additional art objects loaned to the Gallery by Robert Woods Bliss. The cataloging and filing of photographs in the George Martin Richter Archive is continuing, with the gradual enlargement of the collection.

Further activities of the department are indicated under the heading of "Publications."

RESTORATION AND REPAIR OF WORKS OF ART

Necessary restoration and repair of works of art in the Gallery's collections were made by Stephen S. Pichetto, Consultant Restorer to the Gallery. All work was completed in the Restorer's studio in the Gallery, with the exception of the restoration of one painting, work on which was completed in Mr. Pichetto's New York studio.

PUBLICATIONS

During the year an article by Mr. Cairns, "The Future of Musical Patronage," was contributed to a symposium, "Music and Criticism," edited by Richard F. French, published by Harvard University Press, Cambridge, Mass. It also appeared in the Atlantic Monthly. A lec-

ture by Mr. Cairns at the University of Mexico was published by the University of Mexico, and a Spanish translation of an article by Mr. Cairns on "Leibniz' Theory of Law" appeared in an Argentine legal review. Mr. Cairns also edited with an introduction a volume entitled "Lectures in Criticism," to be published in the early fall. His review of Randolph E. Paul's "Taxation for Prosperity" was published in Tax Law Review.

A series of 12 articles on French paintings in the Gallery, prefaced by one entitled "Connoisseurship and Nineteenth-Century French Painting," was published by John Walker in the Ladies' Home Journal. Charles Seymour, Jr., published an article on "XIII Century Sculpture at Noyon" and another entitled "Houdon's Washington at Mount Vernon Reexamined" in the Gazette des Beaux-Arts. Fern Rusk Shapley contributed to the Gazette des Beaux-Arts. Articles and book reviews by James W. Lane appeared in the Gazette des Beaux-Arts, The College Art Journal, Art in America, The American Collector, Antiques, The Catholic World, and Commonweal. Charles M. Richards contributed an article on measurements to Museum News. "A Study of a Painting Done by a Mental Patient," by Erwin O. Christensen, was published in "Case Studies in the Psychopathology of Crime."

A book of illustrations on the painting and sculpture in the Widener Collection was issued during the year. Members of the curatorial staff prepared a check list of the paintings from the Berlin museums, which was placed on sale during the exhibition. A catalog of the paintings presented by Mrs. Ralph Harman Booth was also prepared for the opening of that exhibit.

Since 1941 the history of the Publications Fund has been one of continual growth and development, and the fiscal year 1948 marks another step in providing a varied but well-balanced selection of publications and reproductions for public use.

The Publications Fund has continued to supply color reproductions of fine quality at a moderate price. During the year 8 new 11-inch by 14-inch color reproductions, 8 new color postcards, including 6 subjects from the Index of American Design, and 19 large collotype reproductions were made available. Of the large collotype reproductions, the Publications Fund now has 71 available. A new item was supplied this year in the form of playing-card sets, two of which portrayed subjects from the Index of American Design, and one of reproductions of paintings in the Gallery's collections.

Catalogues of the various collections continue to be popular. During the year, increased distribution exhausted the supplies of the Chester Dale Catalogue, the Preliminary Catalogue of Paintings and Sculpture, and the catalogue entitled Indigenous Art of the Americas. A fifth edition of the Chester Dale Catalogue is on order, and a textual

catalogue of the entire collection to replace the Preliminary Catalogue is in preparation. The end of the fiscal year brought the first shipment of illustrated Widener Catalogues, and plans are in progress for a similar catalogue of the Mellon Collection.

With publication scheduled for 1949 or 1950, the manuscript for Erwin O. Christensen's comprehensive survey of the Index of American Design, "Made in America," is nearing completion. The National Gallery of Art is collaborating with Penguin Books Ltd. in preparing two books, "Popular Art in the United States," by Erwin O. Christensen, to be printed soon, and "Pictures from America," by John Walker, to be issued sometime next year.

EDUCATIONAL PROGRAM

During the year more than 20,000 persons attended the General, Congressional, and Special Topic Tours, while over 24,000 attended the Picture of the Week. Approximately 19,000 came to hear the lectures and other programs in the Auditorium. Special appointments, tours, and conferences were arranged for over 2,000 persons. The Education Department has continued the publication of a monthly Calendar of Events, announcing Gallery activities, including notices of exhibitions, lectures, gallery talks, tours, and concerts. The Calendar of Events was mailed out to more than 3,000 persons a month.

LIBRARY

The library was given 131 books, 447 pamphlets, and 26 periodicals during the year; 439 books, 55 pamphlets, and 608 periodicals were purchased, and 35 subscriptions to periodicals were made. A total of 55 books, 103 pamphlets, and 406 bulletins were received on exchange from other institutions; 265 photographs were received as gifts to the library, and 52 photographs were received on exchange. During the year, 1,249 books were borrowed and returned, 1,175 of which were borrowed from the Library of Congress. For the remaining 74 books, the library was indebted to museums, universities, and public libraries. In addition, by special arrangement, the Gallery received on loan from the Library of Congress a number of other books on art and related subjects.

INDEX OF AMERICAN DESIGN

The Index of American Design continued during the year to be enlarged by gifts and exchanges. Index material was used at the Gallery by 232 persons, while 534 photographs of Index designs were sold for use in commercial design, publications, references, exhibition, and other purposes.

INTER-AMERICAN OFFICE

The Inter-American Office suspended operations at the close of the the fiscal year, and its program of promoting art activities between the American republics was terminated, owing to the discontinuance of funds previously made available to the Gallery for this work.

CARE AND MAINTENANCE OF BUILDING

The installation of the fourth refrigeration machine to provide additional air conditioning for the Gallery building was completed in March 1948. Since that time the machine has been in operation whenever required and has been giving satisfactory service.

During the year the mechanical staff overhauled three of the other refrigeration machines, which would customarily have been done by outside contract. The usual routine work in connection with the structural care and maintenance of the building and its mechanical equipment was carried on throughout the year. Care and improvement of the Gallery grounds also progressed satisfactorily; and considerable replacements were made in the Taxus hedge in various areas. The gardening staff has continued to grow a substantial portion of the smaller plants used for the decoration of the two Garden Courts. Plans are now under way to extend the cold-frame equipment in the southwest moat, to enable the gardening staff to produce more small flowering plants used for decorative purposes.

The equipment in the cafeteria kitchen was rearranged during the year, and additional items were purchased, to facilitate the operation of the cafeteria.

OTHER ACTIVITIES

During the fiscal period a total of 47 Sunday evening concerts were given at the Gallery. The concerts, free to the public, attracted capacity audiences. Five Sunday evening concerts during the month of May were devoted to the Gallery's Fifth American Music Festival, the most successful of these to date.

A total of 155 permits to copy paintings and 107 permits to photograph in the Gallery were issued during the year. Prints of the motion picture on the National Gallery of Art were loaned during the year to 19 institutions.

During the year the photographic laboratory of the Gallery made 13,938 prints, 1,037 black-and-white slides, 891 color slides, 2,611 negatives, in addition to infrared photographs, ultraviolet photographs, and color separation negatives.

OTHER GIFTS

Gifts of books on art and related material were made to the Gallery library during the year by Paul Mellon and others. A sum of money was given by an anonymous donor to enlarge a previously established fund, the income from which will be available for the acquisition of works of art by American artists, and for prizes and awards to American artists.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit has been made of the private funds of the Gallery for the fiscal year ended June 30, 1948, by Price, Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be forwarded to the Gallery.

Respectfully submitted.

HUNTINGTON CAIRNS,
Secretary.

THE SECRETARY,
Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1948:

THE SMITHSONIAN ART COMMISSION

The twenty-fifth annual meeting was held on December 2, 1947, The members assembled at 10:30 a. m. in the Smithsonian Building to pass on the works of art which had been offered during the year. The following action was taken:

Accepted for the National Collection of Fine Arts

Oil, portrait of Mrs. Joseph B. Collins, by G. P. A. Healy (1813–94). Bequest of Miss Susanna Claxton Collins.

Oil, portrait of George Fuller (1822–84), by Edwin T. Billings (1824–93). Gift of Miss Catharine McE. Ames.

Oil, The Fall Season, by Bruce Crane, N. A. (1857–1937). Henry Ward Ranger bequest.

Oil, December Uplands, by Bruce Crane, N. A. (1857–1937). Henry Ward Ranger bequest.

Accepted for the National Portrait Gallery

Marble bust of Capt. John Ericsson (1803–89), by Augustus Saint-Gaudens, N. A. (1848–1907). Marble cut by Jonathan Scott Hartley for Augustus Saint-Gaudens who modified the bust by Horace Kneeland which is now in the National Museum, Stockholm, Sweden. Bequest of Miss Georgiana Wells Sargent.

The members then met in the Regents Room, adjacent, for further proceedings of the annual meeting. The meeting was called to order by the chairman, Mr. Manship. The members present were: Paul Manship, chairman; Dr. Alexander Wetmore, secretary (member, ex officio); and George Hewitt Myers, William T. Aldrich, Mahonri Young, Gilmore D. Clarke, David E. Finley, George H. Edgell, Lloyd Goodrich, John N. Brown, and Archibald G. Wenley. Ruel P. Tolman, Director, and Thomas M. Beggs, Assistant Director, National Collection of Fine Arts, were also present.

The Commission recommended the reelection of William T. Aldrich, James E. Fraser, George H. Edgell, and Lloyd Goodrich for the usual 4-year period.

The following officers were elected for the ensuing year: Paul Manship, chairman; Robert Woods Bliss, vice chairman; and Dr. Alexander Wetmore, secretary.

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The following were elected members of the executive committee for the ensuing year: David E. Finley, chairman, Robert Woods Bliss, and Gilmore D. Clarke. Paul Manship, as chairman of the Commission, and Dr. Alexander Wetmore, as secretary of the Commission, are ex officio members of the executive committee.

THE CATHERINE WALDEN MYER FUND

Four miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

64. William Furness, attributed to Benjamin Trott; from Ray Rink, Baltimore, Md.

65. Matilda Watson (Mrs. John Watson), by Sarah Goodridge (1788–1853); from Bessie J. Howard, Boston, Mass.

66. Clara Bartlet Gregory Catlin (wife of the artist), by George Catlin (1796–1872); from Mary Cogswell Kinney, Washington, D. C.

67. Howes Goldsborough (1775–1841), by James Peale (1749–1831); from Edmund Bury, Philadelphia, Pa.

LOANS ACCEPTED

Twenty bronzes, by Frederic Remington, N. A. (1861–1909): Bronco Buster (small cast), Bronco Buster (large cast), Bronco Buster (Bonnard cast), Comanche Indian, Dragoons, Mountain Trapper, Off the Range, Outlaw, Polo Players, Rattlesnake, Scalp, Scalp, Trooper of the Plains, Wicked Pony, Wounded Bunkie, Indian Head, Head of the Rough Rider, Mountain Trapper, Stampede, and Paleolithic Man; and one bronze by Sally James Farnham, Paleolithic Woman, were lent by the R. W. Norton Art Foundation, Shreveport, La.

One miniature on ivory, Portrait of Miss Goss, by Eda Nemoede Casterton, was lent by the artist.

WITHDRAWALS BY OWNERS

Two oil paintings, Portrait of a Gentleman, by Sir William Beechey, and A Cottage Scene, by Ladbrooke, were withdrawn March 23, 1948, by Mrs. Feroline Perkins Wallach, Administratrix of the Estate of Cleveland Perkins.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

Two oil paintings, Fired On, by Frederic Remington, and Mist in Kanab Canyon, by Thomas Moran, were lent to The Washington County Museum of Fine Arts, Hagerstown, Md., to be included in an exhibition "The American Indian and the West," from September 14 through November 2, 1947. (Returned November 3, 1947.)

An oil painting, Moonlight, by Albert Pinkham Ryder, was lent to the Whitney Museum of American Art, New York City, to be included in an exhibition of paintings by Ryder from October 17 to November 30, 1947. (Returned December 10, 1947.)

Eight pieces of porcelain from the Alfred Duane Pell bequest, were lent to Howard University, Washington, D. C., to be included in an exhibition of ceramics made between 450 B.C. and A.D. 1946, held from October 16 through November 30, 1947. (Returned December 5, 1947.)

Four oil paintings, Grand Canal, Venice; The Windmill, Dordrecht, Holland; Leonie; and Santa Maria della Salute, Venice, by Eugene L. Vail, were lent to the Engineers Club, 1325 E Street NW., Washington, D. C. (Returned June 25, 1948.)

An oil painting, The Flags (The Piazza San Marco, Venice), by Eugene L. Vail, was withdrawn by the National Gallery of Art. This painting was donated to the National Collection of Fine Arts by the artist's widow, subject to the condition that it be offered to the National Gallery of Art at the time it is eligible to become a part of that collection. It is understood that the painting shall be kept in the custody of the National Gallery of Art and may be loaned to the Department of State for the decoration of our Embassy in Ottawa.

An oil painting, Portrait of John Graham of Claverhouse, by Mary Beale, was lent with the consent of the owner, the Bruce Corporation, Ltd., to the British Overseas Airways Corporation, for a Scottish Display, June 21 to 30, 1948.

LOANS RETURNED

A water color, Coal Barge, Capri, 1880, by William H. Holmes, lent to The White House, January 25, 1946, was returned February 10, 1948.

THE HENRY WARD RANGER FUND PURCHASES

The paintings purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, which, under certain conditions, are prospective additions to the National Collection of Fine Arts, and the names of the Institutions to which they have been assigned, are as follows:

Title	Artist	Assignment
120. Sunlight on the Waterfront	Ferdinand E. Warren, N. A. (elect) (1899-).	
121. Village Green	John Pike, N. A. (elect) (1911-).	Hickory Museum of Art, Hickory, N. C.
122. City By-Way	John Taylor (1897-)	
123. Gravel, Fish and Soya Beans	Carl Gaertner (1898-)	Sheldon Swope Art Gallery, Terre Haute, Ind.
124. Lobstermen	Andrew Winter, N. A. (1893-)	
125. Patio Royale, New Orleans	Robert Philipp, N. A. (1895-)	

Since it is a provision of the Ranger bequest that paintings purchased from the fund and assigned to American art institutions may be claimed by the National Collection of Fine Arts during the 5-year period beginning 10 years after the death of the artist represented, three paintings were recalled for action of the Smithsonian Art Commission at its meeting December 2, 1947.

Two Ranger Fund paintings were accepted by the Commission to become permanent accessions of the National Collection of Fine Arts as listed earlier in this report.

One Ranger Fund painting, The Harvest Moon, by Charles Melville Dewey, N. A. (1849–1937), was returned to the Fine Arts Society of San Diego, San Diego, Calif., thus becoming its absolute property.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 470 publications (256 volumes and 214 pamphlets) were accessioned, bringing the total National Collection of Fine Arts library accessions to 11,016, plus the volumes of serials formerly accessioned by the Museum library for the "National Gallery of Art," now the National Collection of Fine Arts.

PRESERVATION

Plaster busts of Lincoln and Harrison, by Charles Henry Niehaus, were bronzed and delivered to The White House for Miss Marie J. Niehaus.

Portraits were cleaned, restored, and revarnished for the following departments: State Department—President Madison, by A. G. Heaton; William Seward, by Rufus Wright; and Hamilton Fish, by Daniel Huntington. Department of Agriculture—Secretary J. M. Rusk, by S. Jerome Uhl. Marine Corps of the Navy Department—Former Commanders Charles G. McCawley and William P. Biddle, by R. N. Brooke; Charles Heywood and John Zeilen, by L. H. Gebhard; and John Harris, by R. LeGrande Johnston.

Many minor repairs have been made to our own specimens.

PAINTINGS COPIED

The portrait of Commodore Stephen Decatur, by Gilbert Stuart, was copied by Casimir Gregory Stapko, Washington, D. C., for the University of Pennsylvania, ROTC.

INFORMATION SERVICE

The large number of requests for information and the volume of photographic prints and post cards sold in the office give evidence of the importance and value of these services. No detailed account has

been kept of the many paintings, sculptures, and other art objects brought and sent in for examination and judgment.

Four outside talks were given to art organizations and service clubs concerning specific material in the National Collection of Fine Arts, or on subjects of general art interest. Service on juries of award was performed for five different art societies holding competitive exhibits.

CHANGE IN DIRECTORSHIP

Ruel P. Tolman, after 35 years with the Institution, including 15 years in which he directed the National Collection of Fine Arts, retired March 31, 1948. He was succeeded by Thomas M. Beggs, formerly professor of art, Pomona College, Claremont, Calif., who had been appointed Assistant Director July 30, 1947, and who became Director April 1, 1948.

SPECIAL EXHIBITIONS

October 6 through 31, 1947.—Exhibition of 78 paintings by Señor and Señora Oscar Garcia Rivera, of Havana, Cuba. A catalog was privately printed.

November 9 through 30, 1947.—The Tenth Metropolitan State Art Contest, held under the auspices of the District of Columbia Chapter, American Artists' Professional League assisted by the Entre Nous Club, consisting of 271 specimens of paintings, sculpture, prints, ceramics, and metalcraft. A catalog was privately printed.

January 7 through 29, 1948.—The Sixth Annual Exhibition of the Florida Gulf Coast Group, consisting of 51 paintings. A catalog was privately printed.

January 16 through February 15, 1948.—The Forty-sixth Annual Exhibition of Miniatures by The Pennsylvania Society of Miniature Painters, consisting of 120 miniatures. Reprint of catalog used in Philadelphia.

March 7 through 28, 1948.—The Fifty-second Annual Exhibition of the Washington Water Color Club, consisting of 190 paintings and prints. A catalog was privately printed.

March 7 through 28, 1948.—The Fifteenth Annual Exhibition of The Miniature Painters, Sculptors and Gravers Society of Washington, D. C., consisting of 168 examples. A catalog was privately printed.

April 4 through 28, 1948.—The Fifty-seventh Annual Exhibition of The Society of Washington Artists, consisting of 69 paintings and 13 pieces of sculpture. A catalog was privately printed.

May 16 through 30, 1948.—Biennial Exhibition of the National League of American Pen Women, consisting of 228 specimens of paintings, sculpture, prints, ceramics and metalcraft. A catalog was privately printed.

June 7 through 29, 1948.—Exhibition of 168 paintings in oil and water color made during three expeditions to Tibet by the French painter Lafugie.

Respectfully submitted.

THOMAS M. BEGGS, *Director.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-eighth annual report on the Freer Gallery of Art for the year ended June 30, 1948.

THE COLLECTIONS

Additions to the collections by purchase were as follows:

BRONZE

47.11. Chinese, Shang dynasty (1766–1122 B. C.; late). Ceremonial tripod of the type *li-ting;* variable gray to green patina; decorated with casting in low and bold relief and in intaglio; strongly projecting flanges; inscription of one character. 0.218 x 0.184.

47.12. Chinese, Chou dynasty (1122–256 B. C.). Covered ceremonial vessel of the type *yu;* smooth variable olive-green to brown patina; decorated with casting in low relief; zoomorphic heads in the round terminating bail handle; inscription of three characters. 0.229 x 0.228.

47.13, 47.14. Chinese, T'ang dynasty (A. D. 618–906). Pair of seated lions cast in bronze and gilded; encrustations of cuprite, azurite, and malachite; details incised; on low square platforms with lotus bases; rectangular mortises and incised characters underneath. 0.092 x 0.052; 0.093 x 0.052.

47.15. Chinese, Chou dynasty (1122–256 B. C.; late). Incense burner of the type *Po-shan Hsiang-lu;* stemcup with high conical cover cast in relief to represent mountain landscape with animals and human figures; entwined dragons in relief around foot; inlaid with gold, silver, turquoise, and carnelian. 0.179 x 0.100.

47.20. Chinese, Chou dynasty (1122–256 B. C.; late). Covered ceremonial tripod of the type *ting;* green patina with encrustations of azurite and malachite; upper part of body, cover, and handles decorated with casting in low relief. 0.385 x 0.493.

48.1. Chinese, Shang dynasty (1766–1122 B. C.; late). Ceremonial vessel of the type *hu;* silvery and grayish-green patina with encrustations of cuprite and malachite; decorated with casting in relief; bovine heads as handle lugs. (Illustrated.) 0.381 x 0.274 x 0.227.

IVORY

48.3, 48.4, 48.5. Chinese, T'ang dynasty (A. D. 618–906). Three figures of carved ivory aged to dark brown; representing three Buddhist deities: the Bodhisattva Avalokiteśvara, the Buddha Maitreya and the Bodhisattva Bhaiṣajyaguru. 0.095 x 0.020; 0.094 x 0.021; 0.095 x 0.020.

LACQUER

47.24. Chinese, Chou dynasty (1122–256 B. C.; late). Shallow cup of wood covered with red and brown lacquer; lateral handles; geometric, floral, and animal decoration; from Ch'ang-sha. 0.050 x 0.171 x 0.152.

MANUSCRIPT

47.19. Persian, Mongol period (early 14th century). Fragment of *Tarjama-i Tārīkh-i Tabarī*, i. e., Bal'amī's Persian translation of Tabarī's *Universal History;* 205 fols.; 33 lines of black *naskhī* per page with captions in red *naskhī*; seven miniatures in color and gold; modern red leather binding; pages 0.410 x 0.285.

PAINTING

47.17. Chinese, Ming dynasty (A. D. 1368–1644). Scroll painting by Hsü Pên dated in correspondence with A. D. 1377; landscape in ink on paper; signature and 11 seals on painting; title, 7 colophons and 18 seals on mounting. (Illustrated.) 0.285 x 4.968.

47.21. Persian (14th or 15th century). Page from a pharmacological treatise; paintings in color on paper of a duck (obverse) and a cock pheasant or jungle cock (reverse); *naskhī* script in black for text, red for headings. (Illustrated.) 0.245 x 0.162.

47.22. Persian (first half 16th century). A galloping Turki horseman painted in black and red on paper; inscription "Portrait of Muḥammad Shah Padishah"; seal. 0.101 x 0.154.

47.23. Persian (late 16th or early 17th century). A dervish in landscape smoking a *qualiūn* pipe held by a disciple; black and colors on paper; Signed by Muḥammad Muḥsin. 0.168 x 0.093.

POTTERY

47.16. Chinese, Ch'ing dynasty, K'ang-hsi period (A. D. 1662–1722). Vase with globular body, low foot and tall, slender neck; thick, rich gray-blue glaze with minute bubbles and brown stained crackle. 0.412 x 0.212.

47.18. Persian, Seljuk period (11th-12th century). Deep bowl of fine white clay; decorated with the figure of a winged griffon carved in the body and covered with blue, green, purple and yellow glazes against the white glaze. (Illustrated.) 0.083 x 0.344.

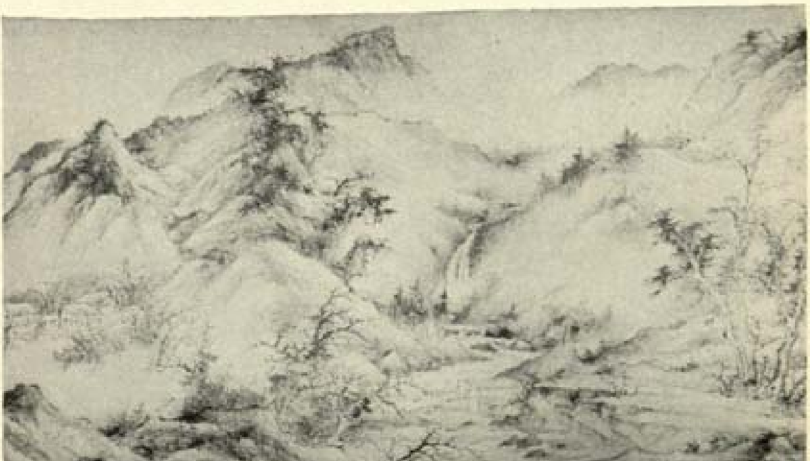
48.2. Chinese, Ming dynasty (A. D. 1368–1644; early). Vase of bottle shape with high spreading foot, slightly spreading neck, and short vertical lip; annular handles and free-moving rings; white porcelain with creamy-white glaze; decorated with phoenixes and dragons finely incised in the clay almost invisible under the glaze. 0.185 x 0.085.

48.6. Chinese, T'ang dynasty (A. D. 618–906). Tomb figurine of a seated man holding a fowl on his left knee and a basket of peas (?) on his right; fine-grained, buff-white clay, partly glazed and the rest painted with black, green, and red. 0.260 x 0.171 x 0.168.

48.7. Chinese, T'ang dynasty (A. D. 618–906). Tomb figurine of a woman seated on the ground holding and feeding a fowl; fine-grained buff-white clay painted with black, green, and red. 0.151 x 0.152 x 0.171.

The work of the staff members has been devoted to the study of new accessions, of objects submitted for purchase, and to general research within the collections of Chinese, Japanese, Arabic, Persian, and Indian materials. Reports, oral or written, were made upon 3,498 objects and 1,108 photographs of objects submitted for examination; and 288 oriental language inscriptions were translated.

48.1



47.17

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART.

47.21

47.18

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART.

REPAIRS TO THE COLLECTIONS

A total of 16 objects were remounted or repaired as follows:

Chinese paintings remounted	10
Chinese painting repaired	1
Chinese sculpture repaired	1
Japanese painting remounted	1
Japanese paintings repaired	2
Japanese pottery repaired	1

The long-overdue task of repairing and restoring the Peacock Room by James McNeill Whistler was begun on October 10, 1947. This work involves taking down all four walls of the room, removing all leather from the original paneling, constructing a complete set of new panels of harborite, reconditioning the leather and cleaning all painted and gilded surfaces, remounting the leather on the new panels by means of a moisture-proof wax adhesive, and reinstalling all panels and shelving. All phases of the actual restoration are being done by Messrs. John A. and Richard M. Finlayson of the Museum of Fine Arts, Boston, on a part-time schedule. All structural work is being done in the Gallery cabinet shop. The work is still in progress.

CHANGES IN EXHIBITIONS

Changes in exhibitions totaled 1,196, as follows:

American arts:	
Paintings	92
Drawings and pastels	32
Prints	43
Arabic arts:	
Bookbinding	4
Glass	2
Manuscripts	35
Painting	16
Wood carving	2
Armenian arts:	
Manuscript	24
Bactrian arts:	
Metalwork	2
Byzantine arts:	
Crystal	2
Metalwork	9
Painting	12
Chinese arts:	
Bronze	100
Jade	42
Metalwork	31
Painting	38
Pottery	31
Textile	2
Wood sculpture	6

CHANGES IN EXHIBITIONS—continued

Coptic arts:	
Manuscript	1
Painting	6
Egyptian arts:	
Pottery	3
Greek arts:	
Manuscript	16
Indian arts:	
Manuscript	6
Painting	145
Sculpture	12
Japanese arts:	
Lacquer	18
Painting	125
Pottery	78
Sculpture	4
Korean arts:	
Bronze	1
Pottery	30
Mesopotamian arts:	
Pottery	8
Persian arts:	
Bookbinding	6
Manuscript	10
Metalwork	23
Painting	124
Pottery	38
Syrian arts:	
Glass	11
Metalwork	5
Veneto-Islamic arts:	
Metalwork	1

ATTENDANCE

The Gallery was open to the public from 9:00 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 77,012. The weekday total was 61,916 and the Sunday total was 15,096. The average weekday attendance was 198, the average Sunday attendance was 290. The highest monthly attendance was in July with 12,230 visitors; the lowest was in December with 3,045 visitors.

There were 1,650 visitors to the main office during the year; the purposes of their visits were as follows:

For general information	1,113
To see staff members	115
To read in the library	266
To make sketches and tracings from library books	17
To see building and installations	46
To make photographs in court and sketches in exhibition galleries	41

To examine, borrow, or purchase photographs and slides		308
To submit objects for examination		433
To see objects in storage		214
Washington manuscripts	10	
Far Eastern paintings and textiles	52	
Near Eastern paintings and manuscripts	11	
Tibetan paintings	1	
American paintings	32	
Whistler prints	4	
Oriental pottery, jade, bronze, lacquer, and bamboo	88	
Gold treasure and Byzantine objects	3	
All sculpture	10	
Syrian and other glass	3	

DOCENT SERVICE, LECTURES, MEETINGS

By request, 16 groups met in the exhibition galleries for instruction by staff members. Total attendance was 311.

On invitation, the following lecture was given outside the Gallery by a staff member:

1948

Feb. 5 — Mr. Pope lectured on "The Pottery and Porcelain of China" at the Chevy Chase Women's Club. Attendance: 30.

The Auditorium was used for meetings as follows:

1947

Nov. 4 — Bureau of Economics, U. S. Department of Agriculture. Attendance: 80.

Nov. 5 — Ditto. Attendance: 155.

Nov. 6 — Ditto. Attendance: 140.

Nov. 7 — Ditto. Attendance: 75.

1948

Jan. 20 — Art Section, Twentieth Century Club; lecture by Mr. Pope. Attendance: 90.

Mar. 4 — Art Section, Chevy Chase Women's Club; lecture by Mr. Pope. Attendance: 20.

Apr. 29 — Division of Dairy Herds Industry, U. S. Department of Agriculture. Attendance: 45.

May 5 — National Conference on Family Life. Attendance: 212.

May 7 — National Conference on Family Life. Attendance: 52.

June 11 — Museum group. Special Libraries Association; lecture by Mr. Pope. Attendance: 36.

Members of the staff traveled outside of Washington for professional purposes as follows:

1947

July 12 — Dr. Ettinghausen in Baltimore, at the Walters Art Gallery, to examine and select Indian miniatures for exhibition in London.

Oct. 4–10 — Mr. Pope in New York and Boston; in the Museum of Fine Arts, attended symposium in connection with exhibition of the Bernat collection; examined objects belonging to museums, private collections, and dealers.

1947

Nov. 12 — Mr. Pope in Baltimore, at the Baltimore Museum of Art, to examine objects of Siamese art and select for exhibition.

Nov. 21 — Mr. Pope in Philadelphia, at the Philadelphia Museum of Art, to examine objects and discuss plans for a proposed exhibition.

Dec. 10–11 — Mr. Wenley in Williamsburg, Va., at the College of William and Mary, to examine Chinese objects and select for exhibition.

1948

Feb. 5 — Dr. Ettinghausen in Baltimore, at the Walters Art Gallery, to examine objects.

Feb. 20–21 — Mr. Pope in New York; examined objects belonging to dealers.

Mar. 29–Apr. 2 — Mr. Wenley in New York; attended annual meeting of the American Oriental Society; at executive committee meeting he reported on the Hackney Scholarship Fund of which he is committee chairman; examined objects belonging to dealers; attended organization meeting of the Far Eastern Association.

Mar. 30–Apr. 2 — Mr. Pope in New York; attended annual meeting of the American Oriental Society; examined objects belonging to dealers; served as temporary secretary at all-day organizational meeting of the Far Eastern Association, and was elected to Board of Directors of the Association.

Apr. 1–14 — Dr. Ettinghausen in New York, Boston, and Cambridge; attended meeting of Committee on Near Eastern Studies of the American Council of Learned Societies; examined objects belonging to museums and dealers; did research in connection with current studies.

Apr. 15–18 — Mr. Wenley in Ann Arbor; at the University of Michigan, conferred with University officers on problems related to Far Eastern studies.

May 14–18 — Dr. Ettinghausen in Boston, Cambridge, New York, Princeton, and Philadelphia for research and conferences in connection with objects in the collections and Gallery publications; in Boston attended meeting of the Archaeological Institute of America to discuss the foundation of an American School of Egyptian Studies in Cairo; examined objects belonging to museums, private collections, and dealers.

May 15–18 — Mr. Pope in Boston, Cambridge, and New York; at the Fogg Museum of Art attended a pottery symposium which resulted in the formation of the Far Eastern Ceramic Group; conferred with editors of Harvard Journal of Asiatic Studies; examined objects belonging to museums, private collections, and dealers.

May 24 — Mr. Wenley and Mr. Rawley in New York; attended symposium on museum lighting at the Metropolitan Museum of Art.

1948
May 25-28.......... Mr. Wenley in Providence, Boston, and Cambridge; attended annual meeting of the Association of Museum Directors at the Museum of the Rhode Island School of Design; at the Fogg Museum of Art and the Museum of Fine Arts, examined bronzes, paintings, and new accessions.

Respectfully submitted.

A. G. Wenley, *Director.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1948, conducted in accordance with the Act of Congress of June 27, 1944, which provides "* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *"

SYSTEMATIC RESEARCHES

Dr. M. W. Stirling, Director of the Bureau, spent the first part of the fiscal year in Washington attending to administrative duties and in preparing a study on "Olmec Jade."

On January 1 Dr. Stirling left for western Panamá where he spent 3½ months in the excavation of four archeological sites on the Azuero Peninsula in cooperation with the National Geographic Society. Two of these were representative of the relatively late Coclé culture. A third was a mound site representing a new culture apparently ancestral to Coclé, while the fourth site was a shell mound near the mouth of the Parita River, which was found to contain a very early and completely new culture, unrelated to anything heretofore known in Panamá. During this work Dr. Stirling was assisted in the field by Dr. Gordon Willey of the Bureau staff.

At the close of the archeological field season a brief visit was made to the Guaymí Indians in the Province of Chiriquí.

Dr. Frank H. H. Roberts, Jr., Associate Director of the Bureau and Director of the River Basin Surveys, was mainly occupied throughout the fiscal year in directing the River Basin Surveys. In connection with this work he established cooperative projects with State and local institutions in various parts of the country, aided in the preparation of preliminary reports pertaining to the results of investigations in various reservoir basins, and wrote progress reports for the cooperating agencies. He went to Lincoln, Nebr., November 26 to December 5, where he inspected the field headquarters and laboratory for the Missouri Basin project, received reports on the results of the summer's surveys in that area, and aided in the preparation of plans for evaluating and handling the material collected. While in Lincoln he attended sessions of the Fifth Plains Conference for Archeology and presided at a symposium on "The Paleo-Indian in the

Central Plains." He also took part in a regional conference of National Park Service officials at which various phases of the River Basins program were discussed and plans for the future were formulated. In May he went to Milwaukee, Wis., to attend the annual meeting of the Society for American Archeology and presided over a symposium on "The River Basin Archeological Surveys." Dr. Roberts' report on the River Basin Surveys appears in another section of this report.

Dr. John P. Harrington, ethnologist, was occupied at the beginning of the fiscal year in the preparation of a supplement to his recently completed Aleutian grammar. This supplement contains a long list of terms relating to natural history, weather, material cultures, sociology, religion, and geography. Following this Dr. Harrington completed a grammar of the Maya language consisting of 750 typewritten pages. This study is of particular importance, as Maya is one of the "classic" languages of aboriginal America.

Dr. Harrington then prepared and brought to completion a grammar of the Cahuilla language. The Cahuilla Indians are at present the leading native tribe of southern California. A large report on the Guaraní language of South America was also finished. Guaraní in the Republic of Paraguay has been given equal official and legal standing with Spanish. This is the only instance in which a native Indian language has been given a true literate status. A smaller paper on the Matako language of the central part of the Gran Chaco of Argentina was next completed. It was found that in many respects this language is surprisingly similar to Guaraní. Another large paper was then prepared, describing and discussing the three principal ideographic writing systems of the world, Egyptian, Chinese, and Maya.

Dr. Henry B. Collins, Jr., ethnologist, spent the period from June 19 to August 16 on Martha's Vineyard, Mass., engaged in an archeological survey of the western end of the island. He found a number of prehistoric Indian village and camp sites, mainly in the Chilmark-Menemsha-Gay Head region, and made collections of artifacts. On returning to Washington he resumed his Eskimo studies.

As chairman of the Board of Governors of the Arctic Institute of North America, Dr. Collins continued to devote considerable time to the affairs of that organization. In the course of the year the Arctic Institute, with increased support from governmental and other sources, expanded its research and other activities. It opened a New York office at the American Geographical Society headquarters, established an open membership, and began publication of a journal. It sponsored and administered a number of field studies in anthropology, botany, zoology, geology, and geography. These projects carried out

in Alaska and northern Canada were financed in large part by the office of Naval Research and the Canadian Government.

Dr. Collins continued to serve as chairman of the Directing Committee for the Arctic Institute's Bibliography and Roster projects. This committee selected personnel and put into operation these two projects—the preparation of a comprehensive annotated and indexed bibliography on the Arctic, and a roster of Arctic specialists. The projects are supported by funds from the Office of Naval Research, the Army, and the Defense Research Board of Canada. The bibliography project, with four expert bibliographers and three assistants, is under way at the Library of Congress; the roster project, with a director and assistant, has been given office space in the building of the Carnegie Institution of Washington.

At the invitation of the Canadian Government, Dr. Collins left Washington late in June to conduct archeological work for the Smithsonian Institution and the National Museum of Canada in the northern part of the Canadian Arctic Archipelago.

At the beginning of the year Dr. William N. Fenton was on leave while teaching in the summer session of Northwestern University (June 23 to August 23), where he was invited to occupy the post of professor in the department of anthropology during that quarter. While in the Chicago area, he was able to spend considerable time examining rare books and manuscripts in the Ayer Collection of the Newberry Library and to study ethnological collections from the Iroquois Indians in the Milwaukee Public Museum and in the Chicago Natural History Museum. Returning, Dr. Fenton spent the first 2 weeks of September at field work among the Seneca Indians of Allegany Reservation in western New York.

Teaching a course in primitive political institutions suggested a plan for undertaking a comprehensive political history of the League of the Iroquois which would attempt to test the findings of ethnology in the historian's traditional materials. The documentary materials on the Six Nations comprising the Iroquois League for the Federal Period alone and for the succeeding first decade of the nineteenth century exist in several large collections of papers which have not been used extensively by historians of Federal and Indian political relations. First, the papers of Samuel Kirkland (1741–1808) contain interesting sidelights on the political activities of the Six Nations, covering missionary activities among the Oneida, Tuscarora, and Seneca tribes; the correspondence of an agent of the American Revolution; and the gradual civilization of the native Indians. Examination of the Kirkland papers at Hamilton College was begun in September with the help of M. H. Deardorff of Warren, Pa., and Charles E. Congdon, an alumnus. The project is indebted to Dr. Arthur C. Parker of Naples, N. Y., for the loan of a Seneca Census of

1840 and several minute books of the Six Nations Council at Buffalo Creek by the New England missionary Rev. Asher Wright; these have subsequently been acquired by the American Philosophical Society.

Two grants were received for Iroquois research. Toward the collection of materials for a political history of the Iroquois the American Philosophical Society made a grant for travel, photoduplication, and secretarial assistance; and a similar grant was received from the Viking Fund, Inc., for field work.

Beginning in February, Dr. Fenton spent about 1 week of each month in travel to repositories of historical materials. He visited Salem and Boston to examine the Timothy Pickering papers, working in the Essex Institute and the Peabody Museum of Salem, and the Massachusetts Historical Society and the Houghton Library of Harvard in the Boston area. Frequent short trips were made to the library of the American Philosophical Society, Philadelphia, to examine parallel papers and to identify a Constitution of the Iroquois Confederacy by Seth Newhouse. In April Dr. Fenton went back to Hamilton College for further work on the Kirkland papers, and returning, he stopped at Vassar College library to arrange for copying the Jasper Parrish papers. Kirkland, Pickering, and Parrish were all concerned in negotiating treaties with the Six Nations after the Revolution, and their letters led to the immense collection of mementos relating to western New York which Henry O'Reilly of Rochester had collected in 15 large folio volumes for presentation to the New York Historical Society. By the end of June Dr. Fenton had completed a first examination of the O'Reilly papers and had arranged for microfilming a substantial part of them. A policy of collecting as much as practicable on microfilm has cut down the cost of travel.

Dr. Fenton completed a term as senior editor of the Journal of the Washington Academy of Sciences. In June he was appointed anthropologist member of the Language Panel of the United States National Commission for UNESCO.

A second album of Iroquois records with program notes, edited by Dr. Fenton, entitled "Seneca Songs from Coldspring Longhouse," was published by the Library of Congress.

Dr. Philip Drucker, anthropologist, was detailed to the River Basin Surveys July 1 to October 1, 1947, for work in the Columbia Basin. He returned to Washington on October 1, and during the ensuing months he brought to completion an ethnographic monograph entitled "The Northern and Central Nootkan Tribes," based on field investigations which he had made among the Nootkan-speaking Indians of Vancouver Island, British Columbia, some years before. This report describes in detail mode of life and customs of these Indians during the closing decades of the nineteenth century and is to be followed by a study tracing the cultural changes produced by European contacts

during the maritime fur trade a century earlier. On finishing this report, he completed an archeological monograph, "La Venta, Tabasco: A Study of Olmec Ceramics and Art," which summarizes the principal results of the studies made by the Smithsonian Institution-National Geographic Society expeditions to southern Veracruz and Tabasco, Mexico. In addition, he prepared two short papers for publication—"Preliminary Account of Archeological Reconnaissance on the Chiapas Coast," and one entitled "The Antiquity of the Northwest Coast Totem Pole"—as well as summary reports for the Director, River Basin Surveys, on the results of investigations of 14 reservoir areas in the Columbia Basin and of 10 in California during the preceding field season.

On May 2 Dr. Drucker proceeded to Boston and Salem, Mass., to examine collections of manuscript materials and museum collections from the period of the maritime fur trade on the Northwest Coast, in the archives of the Massachusetts Historical Society and in the Peabody Museum, Salem. Through the courtesy of officials of those institutions, he was given access to the collections and was able to assemble a considerable amount of unpublished data relating to the problem of culture change due to early European influences. On May 9 he returned to Washington.

On May 13 he was again detailed to the River Basin Surveys and left for the Pacific Coast, to resume charge of the River Basin Surveys work there. He was occupied with these duties at the end of the fiscal year.

Dr. Gordon R. Willey was detailed to the River Basin Surveys for the period August 15 to October 1, 1947, for work in Tennessee.

In the month of October Dr. Willey was occupied in writing additional sections of a report, "Ancon and Supe: Formative Period Sites of the Central Peruvian Coast." This paper is being prepared in conjunction with J. M. Corbett and L. M. O'Neale and is to be published under the auspices of Columbia University. In November and December full time was devoted to a long monograph "Archeology of the Florida Gulf Coast." This involved both writing and a museum survey in late November. Collections were examined in Cambridge, Andover, and New York.

On January 1, Dr. Willey accompanied Dr. Stirling to western Panamá for 3½ months of archeological excavations in Herrera Province. Four sites were examined and stratigraphic tests made in the most promising locations of each. May and June, following the return from Panamá, were occupied with writing the "Archeology of the Florida Gulf Coast." This report should be completed early in September 1948.

In addition to regular research duties, Dr. Willey has attended two meetings of the Institute of Andean Research, of which he is a

member, and a meeting of Florida archeologists held early in August at Daytona Beach. He has also served as assistant editor to American Antiquity, to the Handbook of Latin American Studies, and to the Journal of American Archaeology. For all these journals his work has entailed the covering of recent South American archeological literature.

In the Bureau he has acted as consultant during the final editing of the third and fourth volumes of the Handbook of South American Indians.

The following articles were prepared by Dr. Willey for publication during the year 1947–48: "Culture Sequence for the Manatee Region of West Florida," American Antiquity, vol. 13, No. 3; "The Cultural Context of the Crystal River Negative Painted Style," American Antiquity, vol. 13, No. 4; "A Proto-type of the Southern Cult," American Antiquity, vol. 13, No. 4.

SPECIAL RESEARCHES

Miss Frances Densmore, collaborator of the Bureau, conducted special research on music among the South American Indians and submitted a manuscript entitled "Musical Customs of the Southern Hunter Indians of South America" as compiled from the Handbook of South American Indians.

INSTITUTE OF SOCIAL ANTHROPOLOGY

The Institute of Social Anthropology was created in 1943 as an autonomous unit of the Bureau of American Ethnology to carry out cooperative training in anthropological teaching and research with the other American republics. During the past year it was financed by transfers from the Department of State, totaling $94,882, from the appropriation "Cooperation with the American Republics, 1948." The major activities of the Institute of Social Anthropology during the fiscal year 1948 are as follows:

Washington office.—Dr. George M. Foster continued as director of the Institute of Social Anthropology. He traveled to six South American countries during the period February 14 to April 12, 1948, visiting Institute of Social Anthropology field stations in Popayán, Colombia, Lima, Perú, and São Paulo, Brazil. In addition, courtesy calls were made on anthropologists in Barranquilla and Medellín, Colombia, Quito, Ecuador, Cusco, Perú, La Paz, Bolivia, Rio de Janeiro, Brazil, and Caracas, Venezuela. Dr. Foster also spent 3 weeks in México (November 25–December 15, 1947) reading final proof on Publication No. 6 of the Institute of Social Anthropology.

Brazil.—Drs. Donald Pierson and Kalervo Oberg continued their work in São Paulo in cooperation with the Escola Livre de Sociología

e Política. They gave a number of courses in sociology and anthropology, supplementing other courses given by local professors in the general field of the humanities. Dr. Oberg, accompanied by several advanced students, returned to the Mato Grosso for 3 months, July-September 1947, to complete field work initiated the preceding year among the Terena and Caduveo Indians. Dr. Pierson, assisted by advanced students, continued field work at "A Vila," a *caboclo* community near São Paulo. The proximity of "A Vila" to São Paulo made it possible to utilize week ends and short vacations throughout the year, rather than spending a continuous longer period in the field.

Colombia.—Dr. John H. Rowe continued to represent the Institute of Social Anthropology in Popayán, Colombia, cooperating with the Instituto Etnológico of the Universidad del Cauca. Courses in ethnology, linguistics, and archeology were given to the students enrolled in the Instituto and 2 months of field work was carried out among the nearby Guambiano Indians, August–September 1947. Dr. Rowe also twice visited Bogotá to consult with local anthropologists of the National Ethnological Institute concerning anthropological activities in Colombia. Sr. Gabriel Ospina, formerly a student of Institute of Social Anthropology scientists in México, was named director of the newly established Instituto de Antropología Social of the Escuela Normal Superior. Utilizing field techniques learned while working with Dr. Foster in Tzintzuntzan, México, he began a 4-year anthropological study of the pueblo of Vianí, to train local personnel, and to throw light on the functioning of this aspect of Colombian culture.

México.—Dr. Isabel Kelly and Dr. Stanley Newman continued to represent the Institute of Social Anthropology in its cooperative plan with the Escuela Nacional de Antropología. Because of reduced appropriations as compared to the fiscal year of 1947, it was necessary to terminate studies in cultural geography on August 31, 1947, when Robert C. West left this service. Five courses in ethnology and linguistics were given during the academic year. Dr. Kelly, assisted by four students, returned to Tajín, Veracruz, to continue her study of the Totonac Indians. A photographic exhibit in the Benjamin Franklin Library in May 1947, of Totonac Indian scenes, prepared by Dr. Kelly, received favorable comment from many Mexicans, and was thoroughly described in El Nacional, the official Mexican Government newspaper. Dr. Newman, working with other faculty members and students, and working with native informants brought from the field, continued research on the Otomí and Nahuatl languages.

Perú.—Dr. Allan Holmberg continued to represent the Institute of Social Anthropology in Perú in its cooperative work with the Instituto de Estudios Etnológicos. As in the case of México, reduced appropriations made it necessary to reduce the Peruvian staff; the services of

Dr. Webster McBryde were terminated on September 30, 1947. Dr. Holmberg gave three courses in ethnology during the year; two, including a seminar on field methods, in the Instituto de Estudios Etnológicos, and one in the University of San Marcos. Three months, February through April, 1948, were again spent in the Virú Valley, bringing to a close the studies initiated the preceding year by Dr. Holmberg, Dr. Jorge Muelle of the Instituto faculty, and selected students.

Dr. Holmberg was one of three official United States delegates to the Hylean Amazon Project of the UNESCO in Iquitos, Perú, in May 1948.

Publications.—Institute of Social Anthropology Publications Nos. 4, 5, 6, and 7, appeared during the fiscal year. These are listed with the publications of the Bureau of American Ethnology on page 82.

RIVER BASIN SURVEYS

The River Basin Surveys, a unit of the Bureau of American Ethnology organized to carry into effect a memorandum of understanding between the Smithsonian Institution and the National Park Service providing for the recovery of such archeological and paleontological data and materials as will be lost through the construction of dams and the creation of reservoirs in many of the river valleys of the United States, continued its investigations throughout the year. The work was carried on in cooperation with the National Park Service and the Bureau of Reclamation, Department of the Interior, and the Corps of Engineers, Department of the Army, and was financed by the transfer of $73,800 from the National Park Service to the Smithsonian Institution. These funds were provided in part by the National Park Service and in part by the Bureau of Reclamation.

Most of the work in the field was of a reconnaissance or survey nature, with only a limited testing of sites where such was necessary to determine their extent and character. In a few cases, however, actual excavations were undertaken. The activities involved 18 States and 38 reservoir areas. By the end of the year the number of reservoir basins surveyed, since the first parties started in July 1946, totaled 85. Their distribution is: Virginia 1, West Virginia 2, Georgia 2, Tennessee 1, Oklahoma 2, Texas 5, Colorado (outside of the Missouri Basin) 4, California 13, the Missouri Basin (7 States) 50, and the Columbia Basin (4 States) 15. Those where surveys were under way but not completed by June 30 are not included in this summary. In the various areas visited 1,576 sites were noted and recorded and of that number 250 have been recommended for extensive excavation. The excavations completed or in progress on June 30 were: New Mexico 1, Wyoming 1, Nebraska 1, South Dakota 1, North Dakota 1,

Texas 1, and Washington 1. Preliminary appraisals with recommendations for further work, supplemented by some technical reports, have been completed for all the areas surveyed. Limited editions of 61 have been mimeographed for distribution to the cooperating agencies. The others were in varying stages of being processed at the end of the year. These mimeographed pamphlets have not been made available to the general public because they are not complete archeological reports and are intended to be used only for reference purposes by the Surveys staff while the program is going forward. Reports for general distribution will be issued after the archeological and paleontological work in each unit has been completed.

General direction and supervision of the work in Georgia, West Virginia, Tennessee, Oklahoma, Texas, New Mexico, Colorado (outside of the Missouri Basin), and some of the California projects were from the main office in Washington. Direction of the program in the Missouri Basin was from a field headquarters and laboratory at Lincoln, Nebr., while the activities in the Columbia-Snake Basin were under the supervision of a field office located at Eugene, Oreg.

The assistance and whole-hearted cooperation given to River Basin Surveys staff men in the field by representatives of the National Park Service, the Bureau of Reclamation, and the Corps of Engineers contributed in no small degree to the success of much of the work. At some of the projects temporary office space and storage facilities were provided, at others transportation was furnished, and in a few cases labor was made available to help in emergency excavations where material had to be recovered immediately. The National Park Service not only obtained the funds necessary for carrying on the program as a whole, but also served as the liaison between the Smithsonian Institution and the other governmental agencies to the benefit of all concerned.

Washington office.—The main office of the River Basin Surveys was under the direction of Dr. Frank H. H. Roberts, Jr., throughout the fiscal year. Carl F. Miller, archeologist, continued to operate from this office, while Joseph R. Caldwell joined the staff as archeologist on December 14, 1947, by transfer from the United States National Museum, and Ralph S. Solecki was appointed in the same capacity on March 2, 1948.

Mr. Miller spent the months from the beginning of the fiscal year until January in completing a "Comprehensive Report on the Archeological Aspects of the Buggs Island Reservoir, Virginia and North Carolina." He left Washington on January 10, 1948, in company with Mr. Caldwell, for Augusta, Ga., where they conferred with the Resident Engineer of the Clark Hill project on the Savannah River. From Augusta they proceeded to Lincolnton, Ga., where they established headquarters, January 13, and proceeded to make a survey of

the archeological remains of the area to be flooded by the Clark Hill Reservoir. During the course of this work they located 128 sites, 70 of which will be covered by water when the dam is completed. These sites included former village areas, camps, and stone-chipping stations, with a few mounds. Materials collected from the surface suggest the former presence of at least six sequent cultural groupings in the area, including a considerable number which possibly antedate the introduction of pottery making. Most of the sites are small and, as a result of long-continued cultivation and erosion, few have any depth. Three of them have been recommended for excavation. Two of the latter are representatives of the type of culture which has been named Stalling's Island, and the third is the Rembert Mound Group described by William Bartram in 1791 and partially excavated by C. C. Jones in 1878 and Cyrus Thomas in 1894 but never thoroughly studied. These mounds belong in the so-called Lamar period in the Southeastern cultural sequence.

Miller and Caldwell completed their work at Clark Hill on May 31 and returned to Washington. They spent the remainder of the fiscal year writing a preliminary report on the results of the survey and preparing recommendations and estimates for an excavation program in the basin.

Mr. Solecki left Washington on March 8, 1948, for Hinton, W. Va., where he established headquarters and began a survey of the Bluestone Reservoir Basin on New River. He completed the preliminary reconnaissance on April 19 and left for Huntington, W. Va., to confer with the District Engineer, Corps of Engineers. En route he stopped at Charleston where, with the aid of Mrs. Roy Bird Cook, State Historian and Archivist, he checked the records and manuscripts in the History and Archives Department of West Virginia for possible information on the Indians and early Colonial settlers in the New River valley. He left Huntington on April 21, for Pittsburgh, Pa., stopping to examine some archeological sites at Moundsville, W. Va. At Pittsburgh he obtained information from the District Engineer, Corps of Engineers, about the proposed West Fork Reservoir in the Monongahela Basin in north-central West Virginia. From Pittsburgh he proceeded to the West Fork Reservoir area and made a preliminary reconnaissance of the area that ultimately will be flooded. This work was completed on May 6, and he returned to the Bluestone area for more intensive investigation of the remains occurring there.

Inasmuch as both of the reservoir projects surveyed by Mr. Solecki are in mountainous regions, most of the traces of Indian and Colonial occupation occur along the river bottoms. A total of 42 archeological sites were found in the Bluestone area. These include mound groups, village remains, rock shelters, one location where there are pictographs, and four Colonial forts. At two of the sites, where potsherds were

found on the surface, Solecki did some test digging. The material thus obtained places the cultural horizon in late pre-Columbian times and indicates certain links between the Ohio Valley and the Great Valley of the Shenandoah. Test excavations were also made in the largest of the rock shelters where both historic and prehistoric objects were found, the latter occurring in the deposits to a depth of 5 feet. Because no previous archeological work has been done in this district the excavation of three of the village sites and the large rock shelter has been recommended. Solecki found 14 small sites, presumably places where transient hunting parties had camped, in the West Fork Basin. None of these are of sufficient size or depth to warrant further study and no additional work was recommended. The West Virginia surveys were completed on May 28 and Solecki returned to Washington where he spent the remainder of the fiscal year preparing reports on the results of his investigations.

Dr. Gordon R. Willey, archeologist on the regular staff of the Bureau of American Ethnology, was detailed to the River Basin Surveys during August and September. On August 14 he went to Nashville, Tenn., where he visited the office of the District Engineer for the purpose of obtaining information about the Center Hill project on the Caney Fork River near Baxter, Tenn. From there he proceeded to Baxter and from August 20 to September 12 carried on a survey of the area to be flooded. He found 39 sites consisting of temple mounds, small earth-rock mounds, villages, and caves showing some signs of occupation. Many of the sites proved to be Middle Mississippian in culture and period; some suggested that they belonged in the pre-Mississippian category, and others may even represent the Archaic. The Middle Mississippian designates the period when the people lived in large sedentary communities, depended primarily on intensive agriculture for their subsistence, built temple or substructure mounds, and made characteristic types of pottery and other artifacts. This generally is believed to have been about A. D. 1300 to 1700. Pre-Mississippian also has been called the Burial Mound period, or Southeastern Woodland culture. At that stage the people lived in smaller communities or scattered households, lived primarily by hunting, fishing, food gathering supplemented by a little agriculture. This was during the centuries from approximately A. D. 800 to 1300. The Archaic refers to small, scattered groups of primitive hunters and food gatherers who are believed to have occupied the area prior to A. D. 700. Excavations were recommended for one of the temple-mound sites and one of the earth-rock burial mounds, with testing in some of the village remains. Unfortunately flooding started before this could be accomplished, and the material obtained from the survey constitutes most of our knowledge of that portion of the Cumberland Basin.

After completing the survey at Center Hill, Dr. Willey proceeded to Knoxville, Tenn., where he discussed archeological problems with members of the Department of Anthropology at the University of Tennessee. From there he returned to Washington and prepared his report. He returned to his regular duties as a member of the Bureau staff on October 1.

Oklahoma.—David J. Wenner, Jr., was appointed field assistant on July 29, 1947, and proceeded to make a survey of the Hulah Reservoir basin on the Caney River in Oklahoma. The area to be inundated by this project is not large and he was able to cover it in a few days' time. He found four sites, all apparently camping places, and because of their meager nature, did not believe them worthy of further investigation. From the Hulah region he proceeded to the Fort Gibson Reservoir project on the Grand (Neosho) River. A rapid survey of that basin located 24 sites consisting of 1 mound group, 1 bluff shelter, and the remains of 22 villages or camps. All but three of the sites will be covered by water. The most important is the mound group known as the Norman site. It originally consisted of six earth mounds and a large surrounding village area. Some work was done in four of the lesser mounds a number of years ago by the University of Oklahoma. One of the two remaining mounds is the largest at the site and is connected to an adjacent low mound by a ramp. Small test excavations have been made in the low mound but the large one is virtually intact. It represents a stage of cultural florescênce in the southern United States about which very little is known and may be comparable in scientific wealth to the famous Spiro mounds, located in an adjacent county, destroyed by treasure hunters some 15 years ago. Excavation of the Norman mound probably would provide information essential to dating the Spiro-type culture which presumably was the forerunner of the native Caddo culture of the southern Plains at the beginning of historic times. For this reason thorough investigation of the remaining manifestations at the Norman site was recommended.

Mr. Wenner completed his field investigations on August 15 and proceeded to Norman, Okla., where the University of Oklahoma provided him with facilities for studying the material collected and writing his reports. During the period of the surveys and the preparation of the reports, Dr. Robert E. Bell, of the Department of Anthropology at the University, assisted Mr. Wenner as an advisor and consultant. After completion of the work Mr. Wenner left the Surveys to return to college. He again joined the staff on June 28, 1948, and at the close of the fiscal year was engaged in making a survey of the Tenkiller Ferry Reservoir on the Illinois River in the eastern part of the State. Robert Shalkop and William Mayer-Oakes, student assistants, were aiding in this work.

Texas.—The River Basin Surveys in Texas continued to operate throughout the year from the base and headquarters supplied by the Department of Anthropology at the University of Texas, Austin. Excavations were completed at one project, the survey of another reservoir basin was brought to conclusion, and two others were started and finished.

At the beginning of the year Joe Ben Wheat, archeologist, was engaged in excavations at the Addicks Reservoir. This work was terminated on July 15. Mr. Wheat then proceeded to Austin where he studied the material he had collected and prepared a preliminary report covering both the results of his survey of the Addicks Basin and his excavations in two of the sites located there. He also wrote a paper "Archeological Survey of the Addicks Basin: A Preliminary Report" which was published in volume 18 of the Bulletin of the Texas Archeological and Paleontological Society. He resigned from the Surveys on August 15 in order to return to the university and complete his graduate work.

The excavations at the Addicks Reservoir proved interesting because they revealed a sequence of cultural stages extending from the era before pottery making and agriculture were introduced through succeeding centuries until the beginning of contact with European culture. The period covered is from about A. D. 900 to 1700. Who the people were is not known, but certain postulations may be made. At the time of the first French and Spanish explorations of the region the Akokisa band of the Atakapan occupied the area. Although little is known of the specific culture of this group, it is generally considered to have shared the general Atakapan culture extending into the lower Mississippi Valley. The archeological culture is of the same southeastern pattern, which may point to the Akokisa as being the pre-Columbian inhabitants of the Addicks district.

At the beginning of the fiscal year Robert L. Stephenson, archeologist, was making a reconnaissance of the Whitney Reservoir Basin on the Brazos River north of Waco. This work continued until October 1, although August 2–4 he returned to Austin for the purpose of depositing material collected and of conferring with members of the Department of Anthropology at the University of Texas; August 30 to September 1 he visited the Spanish Fort and other sites in the central Red River area; and September 13–14 he went to a number of archeological locations near Waco, but outside the reservoir basin, for the purpose of gathering comparative data. On August 23 he made a 1½-hour flight over the entire Whitney area, successfully locating archeological sites from the air and obtaining a comprehensive understanding of the district as a whole. He returned to Austin on October 1 and spent most of the following 2 months studying the material collected and writing the preliminary report. He also prepared an ar-

ticle, "Archeological Survey of Whitney Basin," which was published in volume 18 of the Bulletin of the Texas Archeological and Paleontological Society.

During the course of his investigations Mr. Stephenson located and recorded 61 sites in the Whitney Basin. These consist of 14 rock shelters and 47 occupational areas in the open. Two fossil localities were also located. He recommended 32 sites for further testing and excavation. Such work should produce important evidence on the cultural complexes of that portion of Texas.

Mr. Stephenson left Austin on November 26 and went to Lincoln, Nebr., where he studied the field and laboratory methods being used by the Missouri Basin Survey group. While at Lincoln he also attended the Fifth Conference for Plains Archeology and presented a paper on the work which he had been doing in Texas. He returned to Austin on December 5 and on the 9th left to begin a survey of the Dam "B" Reservoir basin on the middle Neches River in the eastern part of the State. This work was completed on January 18, 1948, having been interrupted by a trip to the Whitney Reservoir where 3 days were spent in showing Dr. Theodore E. White, paleontologist, the bone deposits located earlier. While on this trip Mr. Stephenson located a large mound and accompanying village remains on the upper Neches River near Palestine, Tex. From Dam "B" he proceeded to the McGee Bend Reservoir on the lower Angelina River. Inclement weather, however, interfered with active work in the field, and most of the time until February 16 was devoted to studying local collections of artifacts, working on field notes, and on the report on the results of the Dam "B" investigations. During this interval he also went to Galveston, Tex., for a 3-day conference at the office of the District Engineer, Corps of Engineers, regarding the dates of beginning and completion of reservoir projects in all parts of Texas. The period from February 16 to April 15, except for 3 days (March 5-7) spent at Nacogdoches studying old records to obtain data on the early history of the area, was devoted to reconnaissance of the McGee Bend basin. When the survey was finished Mr. Stephenson returned to Austin and was occupied until the end of the year in preparing his reports on the Dam "B" and McGee Bend investigations.

In the survey of the Dam "B" area 12 sites were located, but none gave indication of being of sufficient importance to warrant further examination. Comparable material occurs both in the McGee Bend Basin and elsewhere in the region. Unless construction work should reveal subsurface deposits of archeological significance no additional work will be required at this reservoir and none was recommended. At McGee Bend 80 sites were located and recorded. Of this number, 8 are early and contain no pottery, 34 are early pottery sites of the Alto Focus (ca. A. D. 1000 to 1300), 22 are late pottery sites of Bossier,

Belcher, and Frankston Foci (ca. A. D. 1450 to 1600), and 1 is a historic site. At many of these locations there are evidences of occupation through two or more cultural periods and they are important for that reason. Out of the group 31 sites have been recommended for further testing or more extended excavation.

New Mexico.—The only work done thus far in New Mexico consisted of the excavation of portions of two shallow rock-shelters 8 miles southeast of Tucumcari. The manifestations at that location, the Hodges site, were outside of the area directly involved by the Tucumcari project and were in no danger of destruction either by construction work or flooding. They were being dug, however, on week ends and holidays by workmen from the project and by settlers attracted to the district by the development of the irrigation program. In order to salvage as much as possible of what still remained, the excavations were initiated by Herbert W. Dick, temporary field assistant, who was employed by the Surveys for that purpose. Mr. Dick worked at the Hodges site from August 18 to 26. He found that both shelters contained a homogeneous lot of archeological material representing a late pre-Columbian cultural period in that part of the Southwest. On the basis of potsherds, found in association with the stone and bone artifacts, a late fourteenth or early fifteenth century dating is given to the archeological manifestations. After completing the digging Mr. Dick went to Albuquerque, N. Mex., where he processed the specimens and prepared a preliminary report on his findings.

While Mr. Dick was engaged at the Hodges site it was visited by Dr. Sheldon Judson who was completing a geological study of the San Jon, N. Mex., region for the Smithsonian Institution. Dr. Judson found that the lower deposits in the shelters contained interesting and helpful stratigraphy and from the evidence he obtained there was able to add another link in the "alluvial chronology" which he has established for that district, the chronology which promises to contribute much to the understanding of the complex history of the Late Pleistocene and subsequent periods in the Southwest. Because of this the Hodges site enjoys an importance out of all proportion to its antiquity and the archeological information which it produced.

Colorado.—Investigations in certain portions of Colorado are a part of the major program for the Missouri Basin, but there are a number of others which fall outside that drainage area and which are being conducted as separate units of the Surveys as a whole. These are in the Arkansas and Gunnison Basins. Later they will be expanded to the Colorado-Big Thompson projects and other tributaries of the Colorado.

Donald Eastman and Gary L. Yundt were appointed field assistants on June 7 and immediately began surveys at a number of reservoir basins in the Gunnison drainage. Brief preliminary investiga-

tions had been made at a number of these projects by Western State College, Gunnison, students under the direction of Dr. C. T. Hurst of that institution. Working in conjunction with Dr. Hurst and under his general direction, Eastman and Yundt completed the surveys of the Cottonwood, Cebolla, Gateview, and Almont reservoir areas and at the close of the year were engaged in a reconnaissance of the Taylor Lake project. The four basins where investigations were completed contained 16 sites consisting of both rock shelters and open camps. None appeared to be of sufficient importance to warrant recommendation for further study by the River Basin Surveys. However, Dr. Hurst and Western State College volunteered to take over such of the units as indicated the possibility of contributing some knowledge and assume responsibility for the additional work needed to obtain it.

Arnold M. Withers was appointed to the Surveys staff on June 13 as archeologist and on June 21 left Denver accompanied by W. W. Thompson and M. F. Sullivan, student assistants, to begin the reconnaissance of a number of reservoir projects in the mountains west of Pueblo. This work was going ahead at the close of the fiscal year. Mr. Withers and his associates used space made available by the Department of Anthropology of the University of Denver as their base of operations.

Missouri Basin.—The Missouri Basin project continued in full operation throughout the year. On July 1, three archeological surveys and one paleontological reconnaissance were under way and the headquarters and laboratory at Lincoln, Nebr., were actively engaged in processing data and specimens received from the field parties. Most of the activities were of a survey nature, but some digging was done at Birdshead Cave in the Boysen Reservoir, Wyo., at Medicine Creek Reservoir, Nebr., and at several paleontological sites in Wyoming. By the end of the first week in November weather conditions were such that it was necessary to stop explorations for the season and all regular personnel returned to Lincoln. From then until conditions again became favorable in the spring, the time was devoted to the study of materials and data collected and the preparation of reports. Field work was initiated March 29, 1948, when an extensive series of excavations was started at sites soon to be destroyed by construction operations at the Medicine Creek Dam in western Nebraska. This work was in accordance with an agreement with the Bureau of Reclamation whereby the River Basin Surveys provided the technical supervision and the Bureau of Reclamation furnished the necessary labor and equipment. This undertaking was still in progress at the end of the fiscal year. On June 1 one archeological party left Lincoln for the Angostura Reservoir, S. Dak., for further survey and excavation, and on June 3 another left for Heart Butte Reservoir, N. Dak., to begin similar activities. A paleontological party departed on June 1 for the

Boysen Reservoir area, Wyoming, to resume the collecting of fossil material. All three parties were at those respective locations at the end of the year.

The general results of the Surveys' findings in the Plains were outlined in the 64th Annual Report of the Bureau of American Ethnology and, although subsequent work added important details, need not be repeated. Some mention, however, should be made of the excavations carried on in the present year. Birdshead Cave, located near the base of the Owl Creek Mountains, in the Boysen Reservoir basin, Wyoming, contained several levels of aboriginal debris of occupation separated by layers of decomposed rock and dust. The artifacts recovered, although small in number, show significant differences from level to level. If these specimens can be correlated with those from some of the single-occupation sites in the basin, a task which was being attempted at the close of the year, it may be possible to arrange the latter in a sequential order and thus establish a relative chronology for the area. As a whole the material from upper levels of the cave suggests a late pre-Columbian occupancy by Indians from the Great Basin farther west rather than by people from the Plains. This introduces another set of problems pertaining to the interrelationships between two rather distinct groups over a long period of time. Further work in the area should throw light on the subject.

Excavations at the Medicine Creek Reservoir were carried on from September 5 to November 9, but little more than sampling was undertaken at that time. When the work was resumed in March, large-scale operations became possible through the labor and power machinery contributed by the Bureau of Reclamation. The use of heavy equipment ordinarily is frowned upon by archeologists. Because of the short time available for excavation before the sites were destroyed by construction activities and the lack of funds needed to hire large labor crews, however, it was deemed advisable to use bulldozers and highway-grading machinery to remove the overburden from buried village remains. The results obtained amply demonstrated the practicability and effectiveness of such equipment in uncovering archeological materials with a minimum of breakage, and wherever possible its use probably will be extended to other projects. At Medicine Creek entire sites were stripped of their sod or other cover, making it possible to observe the complete village plan, to study village patterns, and to discover small features not readily determinable by the usual hand-labor methods. From March 29 to June 30 the remains of 25 houses were uncovered, 37 cache pits located beneath their floors were investigated, 13 similar pits outside the houses were examined, and 13 middens were dug. Some 28,000 specimens including utensils made of pottery, tools of bone, stone, and shell, and the remains of various food stuffs such as animal bones, mussel shells and charred

vegetal materials (corn, beans, seeds of sunflower, squash, and wild plum) were found. In a number of cases sections of wood in an excellent state of preservation were obtained from post holes in the house floors. These specimens are of value for determining the type of vegetation in the area hundred of years ago and possibly may furnish information for dating purposes.

Most of the remains in this district belong to the Upper Republican culture, so named because the first of the type studied and defined were located in the Republican River drainage of southern Nebraska. It is not possible at this time to correlate them with any of the known tribes, such as the Dakota, Pawnee, or Comanche, but this may be done later. Remains of this culture are believed to date from ca. A. D. 1200 to 1500. A few of the sites appear to belong to what has been called "Woodland" because of their close relationship to others east of the Missouri. Tentative dating places it in the centuries A. D. 500 to 1200. In addition there are traces of a primitive hunting people who inhabited the area several millennia earlier. There is no doubt that the work at Medicine Creek has added a large and important body of new data on the pre-Columbian inhabitants of western Nebraska and from it an unusually complete picture of life in the area should emerge. It seems evident that several long-held scientific theories regarding those people and their relationship to their environment will need to be revised. The information from Medicine Creek certainly will be one of the most significant contributions yet made to the study of Plains prehistory.

The paleontological work, under T. E. White, while not as important in some ways as the archeological investigations, is making a definite contribution to geology. This is particularly true in the Wind River Basin in Wyoming where data collected by the River Basin Surveys field party has aided in the identification of younger beds than previously had been supposed to be present in the area. Furthermore, no historical summary of paleontology in any of the river basins would be complete without consideration of the fragments of fossil bones and leaves frequently found by archeologists in Indian sites. These objects probably were collected as curiosities, although they occasionally were used as ornaments and sometimes attempts were made to work silicified bones into implements. While not of great significance to paleontology, they are a part of the story, and study of the material is helpful. Thus far 94 reservoir areas in the Missouri Basin have been examined either briefly or in some detail, and specimens have been collected from some 68. In a number of cases this material has helped to clarify understanding of the area and will provide useful data for future reference.

As during the previous year, Dr. Waldo R. Wedel, on detail to the River Basin Surveys from the Division of Archeology, United States

National Museum, was in charge of the program. He prepared general plans and coordinated all phases of the work, making numerous trips of inspection to the areas where surveys and excavations were in progress and supervising the work at Lincoln. He returned to his official station at Washington on October 31, but during the fall and winter months made regular monthly trips to Lincoln to check on the work being done at the field headquarters and laboratory and to assist, through advice and discussion, in the preparation of the reports on the summer's activities. He left Washington on May 26 for Lincoln and on his arrival there resumed active direction of the program for the field season.

J. Joseph Bauxar, archeologist, was at Chamberlain, S. Dak., at the beginning of the fiscal year with the party, under the direction of Paul L. Cooper, which was engaged in making a preliminary reconnaissance of the west side of the Missouri River in the Fort Randall Reservoir area. During the continuance of this work 82 sites were visited, and data on about 20 others were obtained from local people. On July 19 test digging was initiated in some of the more promising sites. The period from July 19 to August 20 was devoted to the examination of burials at the Wheeler Bridge mound site. These occurred in 2 low mounds. At one of these there were 12 bundle burials, and at the other 2, or possibly 3, of the same type. Inasmuch as there were no funerary offerings accompanying any of the burials and the material in the mounds was scarce, there was nothing to indicate possible cultural relationship for these remains. On August 20 Mr. Bauxar shifted his operations to the Pease Creek site where he opened an exploratory trench through a large refuse mound. Two definite occupation levels were noted there, and a large quantity of cultural material was recovered. The specimens suggest affiliation with either Upper Republican or prehistoric Arikara peoples. On September 17 investigations were started at another site which gave indications of a well-defined occupation level. Two trenches were dug at that location. They revealed a well-defined occupation level which extended below the plow zone. This work was completed on October 6, and attention was then turned to the Oldham site where two subsurface circular house floors were uncovered. These presumably belong to a late occupation which apparently was Arikara. Some slight evidence of an earlier Woodland occupation was also noted. A preliminary examination of all the data collected from the various sites investigated indicates a range of cultural types extending back from late historic Yankton through what possibly was early Arikara and even earlier Woodland.

Mr. Bauxar returned to Lincoln on November 6 and from then until April 4 was engaged in working up his material and in establishing an ethnohistory file for the Missouri Basin to be used as a ready

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reference by the staff in correlating archeological materials with those of known tribes. The Thwaites and Biddle editions of the Lewis and Clark journals and the Ordway journal were the sources examined for the desired information. A total of approximately 1,500 items pertaining to tribal locations, contacts, material culture, and other features were extracted from these journals. When this material has been prepared for filing under tribal and subject-matter headings, it probably will fill some 15,000 index cards.

From April 4 to June 26 Mr. Bauxar was on special assignment to the National Park Service for the purpose of conducting historical investigations at the Homestead National Monument in Gage County, Nebr. Five limited areas were examined, and a report on the excavations was prepared and submitted to the National Park Service, Region Two Office, at Omaha. Upon the completion of this detail Mr. Bauxar returned to the Lincoln headquarters and resumed his work on the ethnohistory project.

On July 1 Wesley L. Bliss, archeologist, was working with the field party under his direction at the Glendo Reservoir project in Platte County, Wyo. The survey of this area, started in the month of June, was completed on July 2, and having located a total of 43 sites the party moved the following day to Boysen Reservoir, in Fremont County, where further investigations were carried on until July 26. During this period tests were made in Birdshead Cave in the Owl Creek Mountains about 5 miles west of the dam site. This cave showed six levels of occupation, and prospects for obtaining interesting information about the aboriginal inhabitants of the area were so promising that plans were made to return to it later in the season. On July 27 the party moved to the Oregon Basin project in Park County where it continued reconnaissance work, locating additional sites which increased the total for the basin to 28, and did some test digging in two rock shelters. August 11 it moved to the Canyon Ferry Reservoir near Helena, Mont. Investigations there added to the number of sites located during the preliminary examination of the area in 1946, making a total of 31. The work there was completed on August 26, and attention was turned to the proposed Tiber Reservoir near Shelby, Mont., where work continued until September 9. During this period Mr. Bliss and his party spent 4 days traveling by boat in order to locate and examine sites exposed along the river-cut terraces. These sites could not be reached by land and were not visited during the preliminary reconnaissance made the previous year. Additional sites located bring the total for Tiber to 53. Leaving this area, Mr. Bliss returned to the Boysen Reservoir and from September 11 to November 6 completed excavation of the Birdshead Cave and did some test digging in other sites. He returned to Lincoln on November 8 and from then until the end of the fiscal year was engaged

in laboratory work and the preparation of supplementary reports on the Glendo, Boysen, and Canyon Ferry projects. He also wrote a "Summary Report on the Archeology of the Wyoming-Montana River Basin Surveys of 1947—with Comments on Smokey Hill and Republican River Sub-basins in Kansas and Nebraska." Mr. Bliss presented two papers at the Fifth Conference for Plains Archeology in November. One of these summarized the results of the archeological surveys in Wyoming and Montana and the other discussed the subject of Early Man in the northwest Plains. Mr. Bliss also attended the joint meeting of the American Anthropological Association and the Society for American Archeology at Albuquerque, N. Mex., in December, and presented a paper dealing with archeological problems in the western Plains.

As previously stated, Paul L. Cooper was in charge of a survey party which at the beginning of the fiscal year was operating in the Fort Randall Reservoir area in South Dakota. On July 12 and 13 Mr. Cooper attended a field conference of workers in upper Missouri River archeology at Bismarck, N. Dak., and from there he accompanied Dr. Waldo R. Wedel, field director of the River Basin Surveys, and Dr. Jesse D. Jennings, National Park Service archeologist, on an inspection trip to a site which was being excavated by the University of North Dakota near Fort Yates, N. Dak. From there he returned to Lincoln and until August 4 worked on a preliminary report on the archeological resources of the Fort Randall Reservoir. On August 6, after conferring for 2 days with personnel of the Corps of Engineers in Omaha and with the Director of the University of South Dakota Museum at Vermillion, Mr. Cooper returned to the Fort Randall field unit which had been under the direction of Mr. Bauxar during his absence. From then until October 28 he remained with the field party and participated in the investigations already discussed in connection with Mr. Bauxar's activities. He then returned to Lincoln to take charge of the field headquarters upon the departure of Dr. Wedel for Washington.

Mr. Cooper continued this supervision, which was both technical and administrative, throughout the fall and winter months during the periods when Dr. Wedel was in Washington. He made several trips to Omaha and Denver for the purpose of consulting with officials of the National Park Service, the Corps of Engineers, and the Bureau of Reclamation. As time permitted, the data collected during the field season were summarized preparatory to the writing of technical reports, and preliminary reports were prepared on certain phases of the field work. He also participated in the Fifth Conference for Plains Archeology, presenting a paper summarizing the field work and discussing pottery types found in certain districts in the Plains area. In May Mr. Cooper represented the Missouri Basin project of the River

Basin Surveys at the annual session of the Nebraska Academy of Sciences and read a paper explaining and summarizing the activities of the Surveys. On June 3 Mr. Cooper left Lincoln for North Dakota. Two days were spent en route in conferring with personnel at the University of South Dakota Museum. Arriving at the Heart Butte Reservoir project on the Park River in North Dakota, Mr. Cooper initiated reconnaissance work and started some test excavations in a site not far above the location for the dam. These investigations were in progress at the close of the fiscal year.

Robert B. Cumming, Jr., archeologist, continued to serve as the laboratory supervisor at the Lincoln headquarters. He planned and directed the procedures for processing specimens, photographic negatives and prints, the preparation of maps and diagrams for the reports, the typing of manuscripts and cutting of stencils, and the general maintenance of equipment. During the course of the year 37,406 specimens were cleaned, repaired if necessary, numbered, cataloged, and stored. Since the beginning of the project 59,306 specimens have been processed. Over 830 photographic negatives and their prints were added to the files, bringing the total to 1,256. Approximately 100 kodachrome positives were cataloged, making 179 now available for use in illustrating talks about the program. During the year Mr. Cumming established a file for photographic enlargements suitable for publicity purposes and one for lantern slides. Reference maps and aerial photographs were indexed and filed, 835 of the former and 277 of the latter now being available for use by the staff. In addition Mr. Cumming assisted in and supervised the mimeographing and assembling of reports issued during the year. These consisted of 10 preliminary archeological reports, 5 supplementary archeological reports, and 2 paleontological reports. He also carried on the project inventory and requisitioning of supplies throughout the year. During such times as the field director and acting director were away from Lincoln he was in charge of the field office.

From July 1 to November 7, Jack T. Hughes, archeologist, assisted Wesley L. Bliss in Wyoming and Montana, where he participated in reconnaissance and survey of several reservoir basins. From November 8 to May 30 he worked in the office at Lincoln where he aided in the preparation of various reports on the field work of the 1947 season. He wrote two reports entitled "Supplementary Appraisal of the Archeological Resources of Oregon Basin Reservoir, Park County, Wyoming" and "Supplementary Appraisal of the Archeological Resources of Tiber Reservoir, Toole and Liberty Counties, Montana." He also prepared the following section of a report entitled "Archeology of Birdshead Cave, Fremont County, Wyoming": Introduction, site, locale, occupation, and complexes, as well as parts of those on remains

and conclusions. During this period Mr. Hughes also devoted some of his time to an analysis of the archeological materials in the collection of the Nebraska State Historical Society from the Barn Butte site on the North Platte River in Garden County, Nebr., in the preparation of a report on this site; the preparation of a table showing proposed correlations of geological, climatological, and archeological events at several selected sites in the western United States; and in the preparation of a report on stonework terminology for the Nomenclature Committee of the Conference for Plains Archeology.

Mr. Hughes left Lincoln on June 1 for the Angostura Reservoir in South Dakota where, with J. M. Shippee, field assistant, he began a reconnaissance and intensive survey of the area to be flooded. This work was in progress at the close of the year.

At the start of the fiscal year, Marvin F. Kivett, archeologist, was in charge of a party engaged in an archeological reconnaissance of the proposed Garrison Reservoir in northwest North Dakota. This reconnaissance included surface survey and limited test excavations in a number of the more important of the 70-odd known sites located in and adjacent to the reservoir. These sites include permanent earth-lodge villages, buried occupational zones, burial locations, and numerous tipi-ring groups. The reconnaissance was terminated at Garrison on August 20, and the party transferred its attention to the Baldhill Reservoir on the Sheyenne River, where a brief reconnaissance was carried on from August 22 to August 28. This resulted in the location of 10 archeological sites, 7 of which were occupational areas and 3 were mound groups. All the occupational sites yielded some pottery, while one mound tested yielded four disarticulated burials. The party returned to the River Basin Surveys Laboratory in Lincoln on August 29.

On September 5 Mr. Kivett went to the Medicine Creek Reservoir, Frontier County, Nebr., to do some test digging at several previously located sites. Four pit-house floors, located in two village sites attributable to a variant of the Upper Republican complex, were excavated, and an occupational area located on a low terrace near the mouth of Lime Creek was tested by means of trenches. The latter site presumably is a variant of the Woodland pattern. This work was terminated on November 9 because of inclement weather, and Mr. Kivett returned to Lincoln.

During the period November 10 to March 27 Mr. Kivett prepared preliminary archeological reports for the Baldhill and Garrison Reservoirs in North Dakota, and the proposed Davis Creek Reservoir in Nebraska. He also worked on a technical paper dealing with a shell-bead ossuary excavated during the fall of 1946 on Prairie Dog Creek, Phillips County, Kans., near the upper limits of the Harlan County Reservoir.

On March 28 Mr. Kivett returned to the Medicine Creek Reservoir to begin an extensive excavation program. During the period March 29 to June 30, three village sites on or near the dam axis were excavated, and digging was started at the remains of a fourth village a short distance above the dam in the reservoir basin. This work included the uncovering of 25 house floors, the recovery of 2 burials, and extensive excavations in midden areas associated with the house floors. Power machinery, furnished by the Bureau of Reclamation, was used primarily for removing the sterile overburden covering most of the area, for the removal of refuse dirt, and for digging exploratory test trenches. The bulk of the materials recovered appear to be attributable to the Upper Republican aspect. At the close of the fiscal year the work was continuing, with attention being directed toward a series of small sites on the right bank of the reservoir basin approximately 1 mile above the dam axis.

George Metcalf was appointed field assistant on September 25 and proceeded immediately to the Medicine Creek Reservoir where he joined Marvin F. Kivett in the excavation being conducted there. He returned to Lincoln on November 9 and from then until March 28, when he again went to Medicine Creek, he devoted his time to classifying, studying, and writing a technical paper on the specimens collected during the field work. This report included not only the material obtained by the River Basin Surveys party, but also that secured by a group from the Nebraska State Historical Society which had excavated several house sites in the area during the summer. Mr. Metcalf's manuscript will be incorporated into the major report on the Medicine Creek investigations. On June 30 he was in charge of a portion of the work at Medicine Creek.

J. M. Shippee, field assistant, was with the Bliss party from July 1 to November 8. After his return to Lincoln he devoted the time in the laboratory to work on the specimens from Birdshead Cave, the sorting and classifying of artifacts from other localities, and the preparation of maps. He left Lincoln on June 1 with the Hughes party and was participating in the surveys at Angostura Reservoir at the end of the year.

Dr. Theodore E. White, paleontologist, was occupied in paleontological reconnaissance from July 1 to September 19. In the course of this work he visited 7 reservoir areas in Nebraska, 23 in Wyoming, and 25 in Montana. This phase of his investigations was interrupted from August 21 to September 11 while he dug the skull and several vertebrae of a dinosaur from the Jurassic Morrison beds in the Middle Fork Reservoir area in northeastern Wyoming. Dr. White returned to the Lincoln office on September 20 and spent the time until October 8 preparing preliminary reports on the reservoir projects examined during the summer. He then left for the Rocky Ford and Philip

Reservoir areas in South Dakota and from there proceeded to the Boysen Reservoir in Wyoming where he initiated a survey of the area to be inundated by that project. While in the Boysen Basin he collected a number of specimens of fossil mammals and a large soft-shelled turtle. He returned to Lincoln November 7 and from then until January 6 devoted his time to writing reports and consulting geological literature for information bearing on the reservoir areas.

Leaving Lincoln, Dr. White went to Texas where, from January 9 to 29, he made a paleontological reconnaissance of the Whitney Reservoir basin on the upper Brazos River. From there he returned to Washington, D. C., and from February 2 to May 15 worked in the United States National Museum identifying osteological material obtained from archeological sites, examining specimens, consulting geological literature relative to the reservoir areas in the Missouri Basin and Texas, and preparing reports. He then went to the Lincoln office and devoted the period from May 18 to June 1 making preparations for the summer's field activities. He left Lincoln on June 1 for the Boysen Reservoir where he resumed the investigations interrupted by the onset of bad weather the previous autumn. From June 4 to June 30 he collected a number of specimens of fossil mammals and reptiles and made extensive notes on the structure and stratigraphy of the area.

A number of student assistants were employed during the year as members of the various field parties. Robert L. Hall and Warren Wittry were with the Cooper party in South Dakota from July 1 to September 10, when they returned to college. Both men again joined Mr. Cooper on June 22 and were working with him at the Heart Butte Reservoir at the end of the fiscal year. Gordon F. McKenzie, John L. Essex, and Leo L. Stewart were with Marvin F. Kivett at the Garrison and Baldhill Reservoir projects in North Dakota at the beginning of the fiscal year. Mr. Stewart left the party on August 20, and Mr. Essex and Mr. McKenzie terminated their employment on August 30 following the return to the Lincoln headquarters. H. G. Pierce was with the Bliss party in Wyoming and Montana from July 1 to September 10. John C. Donohoe assisted Dr. Theodore E. White from July 1 to September and again joined him on June 14 for work in the Boysen Reservoir. Ernest Lundelius joined the staff on June 1 and left Lincoln with Dr. White when he started for Wyoming. Both he and Mr. Donohoe were with the White party at the close of the year.

Pacific Coast area.—During the fiscal year the River Basin Surveys project in the Pacific Coast region carried out investigations of the archeological and paleontological resources in 14 reservoir areas in the Columbia Basin, and in 7 reservoir areas in central California. The results of this work were described in reports prepared for mimeographing and limited distribution. A total of 180 sites were found

in the Columbia Basin reservoirs, including sites of major and minor importance, and a total of 80 in those in California.

Dr. Philip Drucker, detailed from the regular staff of the Bureau to serve as field director, was in charge of activities in this area. During the period from July 1 to September 30 he made field headquarters at Eugene, Oreg., utilizing office space made available to the Surveys by the Department of Anthropology of the University of Oregon. He divided his time about equally between the Eugene office, where he planned the survey work and carried out the routine necessary for its operation, and the field, where he at times accompanied the survey parties, and checked on the results of their investigations. At the end of September he departed for Washington, D. C., having closed the field headquarters for the winter. In Washington he prepared the reports previously mentioned on the basis of the data collected by the field parties, in addition to his activities as a member of the staff of the Bureau of American Ethnology.

On May 13 he left Washington for the Pacific Coast, stopping en route at Milwaukee, Wis., for the purpose of conferring with the Committee for the Recovery of Archeological Remains which met in that city on the 14th and of participating in a symposium on the River Basin Surveys program. He arrived at Portland, Oreg., where he conferred with the officials of the Columbia Basin Recreational Survey Office concerning the status of various reservation projects of the Bureau of Reclamation and the Corps of Engineers in the Columbia Basin. On May 18 he arrived in Eugene, Oreg., where he completed arrangements for office and laboratory space at the Department of Anthropology of the University of Oregon. From May 20 to 28 he conferred with officials of the Region Four Office of the National Park Service at San Francisco on plans for the field season, and also with representatives of the departments of anthropology at the University of California, Berkeley, University of California at Los Angeles, and the University of Washington. As the result of these conferences, arrangements were made for two cooperative programs of research. The Department of Anthropology of the University of Washington arranged to put a party in the field under the direction of a member of the River Basin Surveys staff, to make an intensive survey and preliminary testing of the Potholes (O'Sullivan) Reservoir area in eastern Washington. The corresponding department at the University of California arranged to undertake investigations during the latter part of the summer in reservoirs in the upper San Joaquin drainage that had previously been examined by the survey.

During the month of June Dr. Drucker was occupied with planning the itineraries of survey field parties and obtaining the necessary personnel and equipment for them. On June 28 the parties were assembled, given the necessary instructions, and sent into the field. At

the close of the fiscal year Dr. Drucker was at the field headquarters in Eugene.

Franklin Fenega and Clarence E. Smith, archeologists, had just commenced their field work at the beginning of the fiscal year. During the month of July they investigated three reservoir areas in the Willamette River drainage, the Detroit, Dorena, and Meridian, in Oregon. From there they proceeded to the site of the McNary Reservoir on the Columbia River just upstream from Umatilla, Oreg., and Plymouth, Wash., where they continued investigations for the remainder of the summer. All these reservoirs are Corps of Engineers projects. McNary Reservoir they found to be extremely rich in archeological remains, and after the preliminary reconnaissance survey had been completed on August 20, they carried out an intensive survey to establish which of the many sites found would most fruitfully reward excavation. On the basis of their intensive survey it was possible to make recommendations for the excavation of five groups of sites. On completion of the field work they summarized their field data, and submitted a preliminary report. Mr. Fenega resigned from the River Basin Surveys on September 22 in order to return to his academic work at the University of California. Mr. Smith was transferred to temporary headquarters at Berkeley, Calif., on the 22d, and carried out surveys at the following reservoirs in California: Dry Creek, Monticello, Kelsey Creek, Indian Valley, Sly Park, and Wilson Valley. On December 17 he resigned from the Surveys to resume academic work at the University of California.

Richard D. Daugherty, archeologist, and Francis A. Riddell, field assistant, were also just starting field work at the beginning of the fiscal year. During the remainder of the field season they examined the following reservoir areas: Cascade, Smith's Ferry, Scrivers Creek, Garden Valley in Idaho; Equalizing, Long Lake, and Potholes (O'Sullivan) in Washington; Anderson Ranch and Palisades in Idaho; and Hungry Horse in Montana; all projects of the Bureau of Reclamation. The greatest wealth of archeological remains they found to occur in the Bureau of Reclamation's Columbia Basin project, comprising Equalizing, Long Lake, and Potholes (O'Sullivan) Reservoirs. Both men resigned from the River Basin Surveys staff on September 24, having completed the preliminary reports on their field investigations for the season. On June 15, Mr. Daugherty was reappointed to the River Basin Surveys staff and was put in charge of the cooperative project arranged with the Department of Anthropology of the University of Washington. On June 19 he departed for the field with his crew and established a field camp in the Moses Lake area. At the end of the fiscal year he was still in the field in that location, Mr. Riddell was reappointed to the River Basin Surveys staff as field assistant on July 28 and departed with other members of the survey

crew to begin an investigation at Benham Falls Reservoir in eastern Oregon.

George L. Coale, archeologist, Harry S. Riddell, Jr., field assistant, and Douglas Osborne, field assistant, joined the staff of River Basin Surveys on June 28 and proceeded to Benham Falls Reservoir to begin the season's survey work there.

Albert D. Mohr and William S. King, who had assisted Clarence E. Smith during October and November, were employed by the River Basin Surveys temporarily as field assistants during the period May 16–21 to carry out an investigation of the Mariposa Reservoir basin on Mariposa Creek on the east side of the San Joaquin Valley in central California. Only three small sites were located and none were recommended for further investigation.

Cooperating institutions.—State and local institutions have contributed to the River Basin Surveys program in various ways. In addition to furnishing space for field offices and laboratories as at the University of Nebraska, the University of Texas, the University of Denver, Western State College, the University of California, and the University of Oregon, universities and local institutions in some cases have joined forces with the Surveys for cooperative projects and in others have taken over units in the survey program. As previously mentioned, the excavation project at the O'Sullivan Reservoir in Washington was a cooperative undertaking between the University of Washington and the River Basin Surveys. This also was true for the surveys in western Colorado where members of the Surveys staff worked with field parties from Western State College at Gunnison.

During the year the University of Kentucky made surveys at the Wolf Creek Reservoir on the Cumberland River, and at the Dewey Reservoir on Johns Creek in the Big Sandy River drainage. In addition, the University conducted excavations at the Wolf Creek Reservoir and furnished the River Basin Surveys with a detailed report on its activities. The University of Georgia established surveys in the Chattahoochee and Flint River basins and did some excavation work in areas which will be inundated. The Alabama Museum of Natural History did reconnaissance work and some digging. The Florida Park Service took over the survey of the area in Florida which will be flooded by the construction of the Woodruff Dam on the Apalachicola River near Chattahoochee. The University of Tennessee made a survey of the Stewarts Ferry Reservoir basin on Stones River and did preliminary reconnaissance at the Harpeth River project. It also made arrangements for some salvage work at the Center Hill Reservoir where the impounding of water began too soon for the River Basin Surveys to do more than make a reconnaissance and recommend the excavation of certain sites. The University of Missouri, in cooperation with the Missouri Archeological Society, made surveys

in the Bull Shoals, Clearwater, Pomme de Terre, Joanna, Table Rock, and Waco Reservoirs, and carried on excavations in key sites at Bull Shoals and Clearwater. The University of Oklahoma did some excavation work in a village site which will be flooded by the Fort Gibson Reservoir on the Grand (Neosho) River. The University of Kansas did survey work and started excavations at a village site in the Kanapolis River basin on the Smoky Hill River in Kansas. In Nebraska the State Historical Society carried on excavations at archeological sites in the Medicine Creek Reservoir area outside the Federally acquired lands adding important supplemental information on remains beyond the localities being worked by the River Basin Surveys. The Laboratory of Anthropology of the University of Nebraska excavated in two important sites in the Harlan County Reservoir area on the Republican River in the southern part of the State. The University of Nebraska State Museum carried on paleontological work near the Medicine Creek Dam site and on Lime Creek, a tributary of Medicine Creek, where important information was obtained on some of the earliest cultural remains thus far found in North America. The Museum also collected paleontological material from the Harlan County Reservoir. The University of North Dakota, in cooperation with the North Dakota Historical Society, carried on excavations at the Heart Butte Reservoir, on the Heart River, in the summer of 1947, and at the Baldhill Reservoir on the Sheyenne River beginning June 21, 1948. The University of Colorado made a preliminary reconnaissance of the 8 reservoir areas comprising the Colorado-Big Thompson project, while the University of Denver made brief surveys of 12 reservoir basins comprising the Blue-South Platte project. Western State College of Colorado did preliminary work in nine reservoir basins of the Gunnison-Arkansas project. The Museum of Northern Arizona, at Flagstaff, assumed responsibility for surveys at the Alamo project on Williams River in the western part of the State, but had not started investigations at the end of the year. The Archeological Surveys Association of Southern California, sponsored by a number of museums in that area, completed surveys in eight proposed reservoir and flood-control projects in that portion of the State. The University of California, at Berkeley, took over responsibility for the excavation of key sites located by the River Basin Surveys in the Pine Flat Reservoir on King's River and in the Isabella Reservoir on Kern River. Actual operations had not yet gotten under way, however, by June 30.

Progress reports and completed reports prepared by the cooperating organizations are sent to the River Basin Surveys so that the results of their investigations may be coordinated with the over-all

program. All the information obtained by these groups thus becomes a part of the general record of the River Basin Surveys.

EDITORIAL WORK AND PUBLICATIONS

There were issued 1 Annual Report, 2 Bulletin volumes (Handbook of South American Indians), and 4 Publications of the Institute of Social Anthropology as listed below:

Sixty-fourth Annual Report of the Bureau of American Ethnology, 1946–1947, 30 pp.

Bulletin 143. Handbook of South American Indians. Julian H. Steward, editor. Volume 3, The Tropical Forest tribes. 986 pp., 126 pls., 134 figs., 8 maps. Volume 4, The Circum-Caribbean tribes. 609 pp., 98 pls., 79 figs., 11 maps.

Institute of Social Anthropology Publ. No. 4. Cultural and historical geography of Southwest Guatemala, by Felix Webster McBryde. 184 pp., 48 pls., 2 figs., 25 maps.

Institute of Social Anthropology Publ. No. 5. Highland communities of Central Peru: A regional survey, by Harry Tschopik, Jr. 56 pp., 16 pls., 2 maps.

Institute of Social Anthropology Publ. No. 6. Empire's children: The people of Tzintzuntzan, by George M. Foster. 297 pp., 16 pls., 36 figs., 2 maps.

Institute of Social Anthropology Publ. No. 7. Cultural geography of the modern Tarascan area, by Robert C. West. 77 pp., 14 pls., 6 figs., 21 maps.

The following publications were in press at the close of the fiscal year:

Bulletin 143. Handbook of South American Indians. Julian H. Steward, editor. Volume 5, The comparative ethnology of South American Indians. Volume 6, Physical anthropology, linguistics, and cultural geography of South American Indians.

Institute of Social Anthropology Publ. No. 8. Sierra Popoluca speech, by Mary L. Foster and George M. Foster.

Institute of Social Anthropology Publ. No. 9. The Terena and the Caduveo of Southern Mato Grosso, Brazil, by Kalervo Oberg.

Institute of Social Anthropology Publ. No. 10. Nomads of the Long Bow: The Siriono of Eastern Bolivia, by Allan R. Holmberg.

Publications distributed totaled 25,037 as compared with 8,205 for the fiscal year 1947.

LIBRARY

Accessions in the library of the Bureau totaled 145 volumes, bringing the total accession record as of June 30, 1948, to 34,607.

ILLUSTRATIONS

Work on the restoration of Indian photographs consumed the greater part of the year. The rest of the time was spent on work for the editors and on the preparation of maps and illustrations for Bureau publications.

ARCHIVES

Ever-increasing use is being made of the manuscript and photographic collections of the Bureau. Cards for the manuscript catalog, compiled for publication, have been typed and assembled. Upon completion of this project, a similar catalog of the photographic negatives in the Bureau collection, was begun. Approximately 2,600 cards for this catalog were typed by the end of the fiscal year.

The Bureau also put into operation its new filing system of photographic prints, the first installment of 30 albums having been acquired for prints from newly restored negatives. Each print is labeled with information pertinent to the subject. Full biographical data is furnished where possible in the case of portraits, so that the information is easily accessible to inquirers. At the close of the fiscal year, approximately 200 new file prints have been thus filed. Prints for the duplicate reserve file also have been labeled and filed with protecting paper between the prints. Requests for pay orders exceeded 300 prints during the year.

Up to July 1, 1948, 200 restorations of old negatives were completed. This necessitated the making of 200 11- by 14-inch enlargements, 200 mountings, 200 8- by 10-inch negatives, and 600 8- by 10-inch file prints. In addition to the restoration program, the Bureau photographer filled requisitions for 53 negatives, 988 prints, and 807 enlargements.

COLLECTIONS

Collections transferred by the Bureau of American Ethnology to the United States National Museum during the fiscal year were as follows:

Accession No.	*Collection*
177,085.	1 skeleton of an Indian child, 2–3 years old, from near Lela, Wheeler County, Tex.
177,393.	1 skull and 4 cervical vertebrae of a dinosaur. Collected by Dr. Theodore E. White 12½ miles west of Kaycee, Johnson County, Wyo.
178,819.	Archeological material collected at Cerro de las Mesas, Veracruz, México, 1941, by the National Geographic Society-Smithsonian Institution Expedition under the direction of Dr. M. W. Stirling.
178,831.	3 Miocene specimens from the Canyon Ferry Reservoir area in Montana; and 6 Eocene specimens from the Boysen Reservoir area in Wyoming. Collected by Dr. T. E. White and John C. Donohoe.
178,942.	538 specimens of archeological material collected by Dr. Gordon R. Willey from the Center Hill Reservoir on Caney Fork River, DeKalb County, Tenn.
179,088.	2 mollusks from Medicine Creek, Nebr.

MISCELLANEOUS

During the year Dr. Antonio J. Waring of Savannah, Ga., was made a collaborator of the Bureau of American Ethnology, while Miss Frances Densmore and Dr. John R. Swanton continued as collaborators.

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the American Indians, both past and present, of both continents. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Respectfully submitted.

M. W. Stirling, *Director.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1948.

The Smithsonian Institution is the official United States agency for the exchange with other nations of governmental, scientific, and literary publications. This exchange is carried on throughout the world under various conventions, treaties, and other international agreements.

The number of packages received for transmission during the year was 760,119, an increase over the previous year of 56,321. The weight of these packages was 812,189 pounds, an increase of 38,214 pounds. The average weight of the individual package is approximately 1 pound, 1 ounce, as compared with the average of the previous year of 1 pound, 2 ounces—an indication that the institutions are shipping less of the material that was held during the war. The material received from both foreign and domestic sources for distribution is classified as shown in the following table:

	Packages		Weight	
	Number	*Number*	*Pounds*	*Pounds*
United States parliamentary documents sent abroad	346,768		163,262	
Publications received in return for parliamentary documents		3,230		6,993
United States departmental documents sent abroad	186,020		224,063	
Publications received in return for departmental documents		3,192		12,034
Miscellaneous scientific and literary publications sent abroad	198,635		346,645	
Miscellaneous scientific and literary publications received from abroad *for* distribution in the United States		22,274		59,192
Total	731,423	28,696	733,970	78,219
Grand total	760,119		812,189	

The packages are forwarded partly by mail direct to the addressees and partly by freight to the foreign exchange bureaus. The number of boxes shipped to the foreign exchange bureaus was 3,107, an increase of 529. Of the boxes shipped 533 were for depositories of full sets of the United States Government documents furnished in exchange for the official publications of foreign governments for deposit

in the Library of Congress. The number of packages forwarded by mail was 197,355.

The first shipments of exchange publications to the Japanese Exchange Bureau, under the jurisdiction of the National Library of Japan (the former Imperial Library), were made during the year.

In spite of the fact that considerable savings in transportation cost were effected by exporting from Baltimore instead of New York, and in spite of the advantage gained through special arrangements for shipments to Germany, the allotment for transportation was practically exhausted by the end of March 1948. Therefore, it was necessary to curtail shipments sharply during the last 3 months of the fiscal year 1948, which resulted in a backlog at the end of the year of approximately 225,000 pounds.

Consignments are now forwarded to all countries except Rumania, with which country negotiations were continued through diplomatic channels to effect the resumption of normal exchange relations.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of United States official publications received by the Exchange Service to be sent abroad in return for the official publications sent by foreign governments for deposit in the Library of Congress is 94 (57 full and 37 partial sets). The Bulgarian Bibliographical Institute has been added to the list as the official depository of Bulgaria.

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo, Biblioteca y Legislación Extranjero, Ministerio de Relaciones Exteriories y Culto, Buenos Aires.
AUSTRALIA: Commonwealth Parliament and National Library, Canberra.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
QUEENSLAND: Parliamentary Library, Brisbane.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
TASMANIA: Parliamentary Library, Hobart.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
AUSTRIA: National Library of Austria, Vienna.
BELGIUM: Bibliothèque Royale, Bruxelles.
BRAZIL: Instituto Naçional do Livro, Rio de Janeiro.
BULGARIA: Bulgarian Bibliographical Institute, Sofia.[1]
CANADA: Library of Parliament, Ottawa.
MANITOBA: Provincial Library, Winnipeg.
ONTARIO: Legislative Library, Toronto.
QUEBEC: Library of the Legislature of the Province of Quebec.
CHILE: Biblioteca Nacional, Santiago.
CHINA: Ministry of Education, National Library, Nanking, China.
PEIPING: National Library of Peiping.
COLOMBIA: Biblioteca Nacional, Bogotá.

[1] Added during the year.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Ministerio de Estado, Canje Internacional, Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Offentliche Wissenschaftliche Bibliothek, Berlin.[2]
GREAT BRITAIN:
ENGLAND: British Museum, London.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
HUNGARY: Library of Parliament, Budapest.[3]
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Ministerio della Publica Istruxione, Rome.
JAPAN: National Library of Japan, Tokyo.
MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, Mexico, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORTHERN IRELAND: H. M. Stationery Office, Belfast.
NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
PHILIPPINES: National Library, Manila.
POLAND: Bibliothèque Nationale, Warsaw.
PORTUGAL: Biblioteca Nacional, Lisbon.
RUMANIA: Academia Română, Bucharest.[2]
SPAIN: Cambio Internacional de Publicaciones, Avenida Calvo Sotelo 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.
UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.
UNITED NATIONS: Library of the United Nations, Geneva, Switzerland.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Ministère de l'Education, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.
BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
BRAZIL:
MINAS GERAES: Directoria Geral e Estatistica em Minas, Bello Horizonte.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BURMA: Secretary to the Government of Burma, Education Department, Rangoon.

[2] Temporarily suspended.
[3] Changed from Library, Hungarian House of Delegates, Budapest.

CANADA:

ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Provincial Library, Victoria.
NEW BRUNSWICK: Legislative Library, Fredericton.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
SASKATCHEWAN: Legislative Library, Regina.

CEYLON: Chief Secretary's Office, Record Department of the Library, Colombo.
DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.
ECUADOR: Biblioteca Nacional, Quito.
GREECE: National Library, Athens.[4]
GUATEMALA: Biblioteca Nacional, Guatemala.
HAITI: Bibliothèque Nationale, Port-au-Prince.
HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.
Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.
INDIA:

BIHAR AND ORISSA: Revenue Department, Patna.
BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
WEST BENGAL: Library, Bengal Legislature, Assembly House, Calcutta.

IRAN: Imperial Ministry of Education, Tehran.
IRAQ: Public Library, Baghdad.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.
MALTA: Minister for the Treasury, Valleta.
NEWFOUNDLAND: Department of Home Affairs, St. John's.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
PANAMA: Ministerio de Relaciones Exteriores, Panama.
PAKISTAN: Chief Secretary to the Government of Punjab, Lahore.
PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.
SALVADOR:

Biblioteca Nacional, San Salvador.
Ministerio de Relaciones Exteriores, San Salvador.

SIAM: National Library, Bangkok.[5]
VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 73 copies of the Federal Register and 66 copies of the Congressional Record. The countries to which these journals are being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:

Biblioteca del Congreso Nacional, Buenos Aires.
Biblioteca del Poder Judicial, Mendoza.[6]
Cámara de Diputados, Oficina de Informacion Parliamentaria, Buenos Aires.
Boletín Oficial de la República Argentina, Ministerio de Justica e Instrucción Pública, Buenos Aires.

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[4] Added during the year.
[5] Changed from Department of Foreign Affairs.
[6] Federal Register only.

AUSTRALIA:

Commonwealth Parliament and National Library, Canberra.

NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.

QUEENSLAND: Chief Secretary's Office, Brisbane.

WESTERN AUSTRALIA: Library of Parliament of Western Australia.

BRAZIL:

Biblioteca do Congresso Nacional, Rio de Janeiro.

Imprensa Nacional, Rio de Janeiro.[8]

AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manáos.

BAHIA: Governador do Estado da Bahia, São Salvador.

ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.

RIO GRANDE DO SUL: Imprensa Oficial do Estado, Porto Alegre.

SERGIPE: Biblioteca Publica do Estado de Sergipe, Aracajú.

SÃO PAULO: Imprensa Oficial do Estado, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CUBA:

Biblioteca del Capitolio, Habana.

Biblioteca Publica Panamericana, Habana.[8]

EL SALVADOR: Library, National Assembly, San Salvador.[7]

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.[8]

FRANCE:

Bibliothèque, Chambre des Députés, Paris.

Bibliothèque, Consèil de la Republique.

Publiques de l'Institute de Droit Compare, Université de Paris, Paris.[8]

GREAT BRITAIN: Printed Library of the Foreign Office, London.

GREECE: Library, Greek Parliament, Athens.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA:

Civil Secretariat Library, Lucknow, United Provinces.[8]

Legislative Assembly Library, Lucknow, United Provinces.

Legislative Department, Simla.

IRELAND: Dail Eireann, Dublin.

ITALY: International Institute for the Unification of Private Law, Rome.[8]

MEXICO:

Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.

Biblioteca Benjamin Franklin, Mexico, D. F.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

CAMPECHE: Gobernador del Estado de Campeche, Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.

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[7] Added during the year.

[8] Congressional Record only.

MEXICO—Continued

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

JALISCO: Biblioteca del Estado, Guadalajara.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periodico Oficial, Palacia de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado, de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala. Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departmento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Lima.

POLAND: Ministry of Justice, Warsaw.[a]

SPAIN: Diputacion de Navarra, San Sebastian.

SWITZERLAND: Bibliothèque, Bureau International du Travail, Geneva.[a]

UNION OF SOUTH AFRICA:

CAPE OF GOOD HOPE: Library of Parliament, Cape Town.

TRANSVAAL: State Library, Pretoria.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE AGENCIES

Exchanges are sent to all countries except Rumania. The countries listed are those to which shipments are forwarded by freight. To other countries not appearing on the list, packages are forwarded by mail.

LIST OF AGENCIES

AUSTRIA: Austrian National Library, Vienna.

BELGIUM: Service des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CHINA: Bureau of International Exchange, National Central Library, Nanking.

CZECHOSLOVAKIA: Bureau des Echanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–100.

DENMARK: Institut des Échanges Internationaux, Bibliothèque Royale, Copenhagen K.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsinki.

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[a] Federal Register only.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richelieu, Paris.

GERMANY: Offentliche Wissenschaftliche Bibliothek, Berlin.[10, 11]

German Central Committee for Distribution of Cultural Materials, Stuttgart.[10, 12]

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83/84 Berwick Street, London, W.1.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

ITALY: Ufficio degli Sambi Internazionali, Ministero della Publica Istruzione, Rome.

JAPAN: International Exchange Service, National Library of Japan, Uyeno Park, Tokyo.[10]

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.[13]

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.[13]

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédérale, Berne.

TASMANIA: Secretary to the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

Respectfully submitted.

D. G. WILLIAMS, *Acting Chief.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

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[10] Distribution under supervision of War Department.

[11] For all sectors of Berlin and Russian Zone.

[12] For American, British, and French Zones.

[13] Shipments suspended.

FRANCE: Service des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richelieu, Paris.
GERMANY: Öffentliche Wissenschaftliche Bibliothek, Berlin.[2]
German Central Committee for Distribution of Cultural Materials, Stuttgart.[3]
GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 83–84 Berwick Street, London, W. 1.
HUNGARY: Hungarian Libraries Board, Parliament, Budapest, IV.
INDIA: Superintendent of Government Printing and Stationery, Bombay.
ITALY: Ufficio degli Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.
JAPAN: International Exchange Service, National Diet Library of Japan, Ueno Park, Tokyo.[1]
NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.
PALESTINE: Jewish National and University Library, Jerusalem.[4]
POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.
PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.
RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.[4]
SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.
SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédéral, Berne.
TASMANIA: Secretary to the Premier, Hobart.
TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.
UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.
UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.
VICTORIA: Public Library of Victoria, Melbourne.
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Respectfully submitted.

D. G. WILLIAMS, *Acting Chief*.

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

[1] Distribution under supervision of War Department.
[2] For all sectors of Berlin and Russian Zone.
[3] For American, British, and French Zones.
[4] Shipments suspended.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1948.

An appropriation of $455,400 for the operations of the Zoo was provided in the District of Columbia appropriation act. Subject to minor changes in final bills, a total of $441,200 was expended for all purposes, and an unexpended balance of $14,200 remains. This saving was almost entirely from salaries because of the impossibility of filling positions promptly.

The year was a very satisfactory one. Animals of exceptional interest were received; fair progress was made in recruiting the organization, although it still is not fully manned; and some repair work was accomplished.

Minor improvements included the construction of 1,200 linear feet of concrete copings and 12,000 square feet of bituminous concrete sidewalks around some of the animal exhibits and adjacent to roadways; surfacing 4,800 square yards of parking area near the Harvard Street entrance and a short length of service road with penetrating oil and slag covering; constructing and placing 48 park benches made with concrete legs and wood slats.

Chemical fighting of poison ivy was continued with good success. Supplies of building maintenance material which had become badly depleted were somewhat replenished, and some construction, repair, and maintenance equipment was obtained. As a whole the physical condition of the establishment has been improved by concentrating on the places that were most in need of attention.

The National Zoological Park renders a variety of services to the American public. Besides the public exhibits of nearly 2,800 animals and the providing of an attractive recreation area, opportunities are offered for students of biology, particularly vertebrate zoology, as well as for artists, photographers, writers, and research workers—provided the method of research does not endanger the welfare of the animals or of the public. Other direct services are answering in person, by phone, mail, and telegraph, questions regarding animals, their care and transportation; the furnishing of information to other

zoos and private and public agencies regarding structures for keeping and housing animals; cooperation with other agencies of the Federal, State, and Municipal governments in research work.

NEEDS OF THE ZOO

The two chief needs of the Zoo are: 1, sufficient funds for a minor increase in personnel and to provide for proper care of the animals and the maintenance of the establishment in a presentable condition; 2, new buildings to replace antiquated structures that have long since ceased to be suitable for the purpose, presentable, or even safe for use. The more urgently needed buildings are: (1) a new administration building to replace the 143-year-old historic landmark now in use for an office building for the Zoo, but which is neither suitably located nor well-adapted for the purpose. This building is in an excellent location for a public recreational structure and could probably be rehabilitated and used for recreational purposes, perhaps as a children's museum, and thus maintained as a historic building. The new office building should be better located both from the standpoint of accessibility to the public and convenience for the administration of the Zoo; (2) a new building to house antelopes and other medium-size hoofed animals that require a heated building.

VISITORS

It had been anticipated that after the war the fluctuation in attendance during the week would again be pronounced. It has therefore been surprising to note that attendance on early days of the week has been relatively high, and the peak attendance of the week ends has been less pronounced than before the war. This is probably due to continued high employment in the Washington area and to increase in travel accompanying the general economic prosperity.

The total attendance was 3,040,540, an increase in 309,862 over the previous year and the second largest year's attendance the Zoo has ever had.

ESTIMATED NUMBER OF VISITORS FOR FISCAL YEAR 1948

July (1947)	434,500	February	98,250
August	359,200	March	300,590
September	297,800	April	341,800
October	232,100	May	325,700
November	110,500	June	385,600
December	110,500		
January (1948)	44,000	Total	3,040,540

Groups came to the Zoo from schools in 27 States, some as far away as Maine, Florida, Texas, and Wisconsin.

NUMBER OF GROUPS FROM SCHOOLS

	Number of groups	Number in groups		Number of groups	Number in groups
Alabama	3	111	New Jersey	23	1, 807
Connecticut	4	241	New York	51	3, 682
Delaware	8	285	North Carolina	91	3, 230
District of Columbia	112	5, 539	Ohio	44	1, 737
Florida	2	297	Oklahoma	1	27
Georgia	30	1, 709	Pennsylvania	192	9, 290
Illinois	1	31	Rhode Island	1	63
Indiana	7	232	South Carolina	10	339
Kentucky	4	326	Tennessee	22	867
Maine	7	546	Texas	1	16
Maryland	505	30, 208	Virginia	290	16, 145
Massachusetts	9	579	West Virginia	27	1, 241
Michigan	5	434	Wisconsin	1	81
Missouri	2	66			
New Hampshire	1	120	Total	1, 454	79, 249

About 2 p. m. each day the cars then parked in the Zoo are counted by the Zoo police and listed according to the State, Territory, or country from which they came. This is, of course, not a census of the cars coming to the Zoo but is valuable in showing the percentage of attendance by States of people in private automobiles. The tabulation for the fiscal year 1948 is as follows:

	Percent		Percent
Washington, D. C.	27. 4	Ohio	1. 6
Maryland	26. 2	West Virginia	1. 04
Virginia	20. 1	New Jersey	1. 01
Pennsylvania	4. 5	Illinois	1. 01
New York	2. 3	Massachusetts	. 9
North Carolina	1. 9	Florida	. 8

The cars that made up the remaining 11.24 percent came from every one of the remaining States, as well as from Alaska, Alberta, British Columbia, Canal Zone, Cuba, Great Britain, Hawaii, Manitoba, Mexico, Newfoundland, Nova Scotia, Ontario, Panama, Philippine Islands, Puerto Rico, Quebec, Saskatchewan.

It is well known that District of Columbia, Maryland, and Virginia cars bring to the Zoo many people from other parts of the United States and of the world, but no figures are available on which to base percentages.

THE EXHIBITS

Animals for the collection are acquired by gift, deposit, purchase, exchange, births and hatchings, and are removed by return of specimens on deposit, exchange, or death. Although depositors are at liberty to remove the specimens that they place in the Zoo, many leave the specimens for the rest of their lives.

The animal collection has been definitely improved during the year. The total number of specimens on hand June 30, 1948, was 2,797, or 210 less than a year ago, but the collection as a whole is more valuable because of the addition of a number of rare animals.

STATUS OF COLLECTION

Class	Species	Individuals	Class	Species	Individuals
Mammals	196	709	Insects	1	100
Birds	339	1,064	Arachnids	2	3
Reptiles	100	506	Mollusks	2	12
Amphibians	25	179			
Fish	25	224	Total	690	2,797

SUMMARY

Animals on hand July 1, 1947	3,007
Accessions during the year	1,041
Total number of animals in collection during the year	4,048
Removals for various reasons such as death, exchanges, return of animals on deposit, etc	1,251
In collection on June 30, 1948	2,797

ACQUISITION OF SPECIMENS

Air transportation of specimens of moderate weight but of unusual interest has brought to the Zoo some of the outstanding exhibits of the year, including the collection of tarsiers, cloud rats, tree shrews, monkey-eating eagle, and other specimens brought from the Philippines by Charles Wharton. The National Geographic Society sent by air from Santa Cruz, Bolivia, to Washington a pichi ciego mayor (*Burmeisteria retusa*), a small, very peculiar type of armadillo, which is a great rarity in collections. It was alive when it arrived in Miami, Fla., but unfortunately died before it reached Washington. However, the National Museum gained a valuable specimen and some of the Washington biologists had their first glimpse of the remarkable little creature. This may be the first one to have arrived alive in the United States.

The outstanding animals received during the year were:

4 King penguins.
28 Mindanao tarsiers.
9 Philippine tree shrews.
7 Bushy-tailed cloud rats.
1 Monkey-eating eagle.
3 Coconut crabs.
1 Sitatunga.
6 Giant racquet-tailed drongos.
8 Emperor penguins.
4 Adelie penguins.
1 Arctic fox.
2 Snow buntings.
104 Elephant shrews. These were brought to the United States from East Africa by the Medical Division of the United States Navy for studies of tropical diseases, and were quartered at the Zoo until the Navy could provide quarters for them.

As in any colony of living things, there is a steady turn-over, so that the exhibits are constantly changing. Thus, the inventory list of specimens in the collection on June 30 of each year does not show all the kinds of animals that were exhibited during the year; sometimes creatures of outstanding interest at the time they were shown are no longer in the collection at the time the list is prepared.

1. PHILIPPINE MONKEY-EATING EAGLE (PITHECOPHAGA JEFFERYI) AND AN AMERICAN SPARROW HAWK ON THE HAND OF MRS. JOHN N. HAMLET.

Photograph by John N. Hamlet.

2. PHILIPPINE TREE SHREW (UROGALE EVERETTI).

Photograph by Ernest P. Walker.

1. MINDANAO TARSIER (TARSIUS CARBONARIUS).
Photograph by Ernest P. Walker.

2. BUSHY-TAILED CLOUD RAT (CRATEROMYS SCHADENBERGI).
Photograph by Ernest P. Walker.

DEPOSITORS AND DONORS AND THEIR GIFTS

(Deposits are marked *)

Abbott, Capt. J. M., Fort Belvoir, Va., through Dr. John Aldrich, of Fish and Wildlife Service, bald eagle.
Abramson, Dr. Alfred, Arlington, Va., 3 Pekin ducks.
Aburrow, Margaret, Washington, D. C., Pekin duck.
Allen, Arthur, Washington, D. C., Pekin duck, red-shouldered hawk.
Allen, George and John Jr., Tehran, Iran, 2 Syrian brown bears.
Allen, Mrs. Stanley, Washington, D. C., French salamander.
Animal Rescue League, Washington, D. C., white-tufted marmoset.
Arnold, J. O., Silver Spring, Md., Pekin duck.
Baker, Adelbert R., Washington, D. C., box turtle.
Bartsch, Dr. Paul, U. S. National Museum, Washington, D. C., mourning dove.
Bayer, F. N., Smithsonian Institution, Washington, D. C., 3 coconut crabs.
Beauchart, Harry J., Washington, D. C., 11 golden hamsters.
Bell, Donald, Washington, D. C., eastern robin.
Berrey, H. K., Jr., Washington, D. C., 3 horned lizards.
Bialock, A. D., Orinda, Calif., 2 yellow-billed magpies, 2 Boyle's king snakes, 8 California house finches, yellow-billed magpie.*
Boswell, William, Washington, D. C., red-tailed hawk.
Boys of Camp Letts, Y. M. C. A., Edgewater, Md., 2 black vultures.
Brady, Morris K., Washington, D. C., 2 cuzumbies.
Bricker, Mrs., Kensington, Md., 5 opossums.
Brill, Wallace, Jr., Washington, D. C., Cooper's hawk.
Brown, J. A., Chevy Chase, Md., 2 Pekin ducks.
Brozyna, C. A., Takoma Park, Md., 2 grass paroquets.
Bullock, Carl, Bethesda, Md., domestic rabbit.
Burgess, H. E., Washington, D. C., 4 golden hamsters.
Butcher, David H., Falls Church, Va., 2 Pekin ducks.
Calhoun, Frank, Clinton, Md., domestic sheep.*
Carter, C., Winchester, Va., rhesus monkey.*
Chicago Zoological Park, Brookfield, Ill., 2 sitatungas.
Christopher, L. C., Arlington, Va., 2 Pekin ducks.
Clark, W. R., Arlington, Va., barred owl.
Clarry, Warren A., Arlington, Va., 2 barred owls.
Clemm, Frank, Arlington, Va., loggerhead turtle.
Cleveland Zoological Park, through Fletcher Reynolds, Cleveland, Ohio, 2 massasaugas.
Conger, Richard, Washington, D. C., 2 box turtles.
Couch, V. L., Arlington, Va., 2 Pekin ducks.
Craig, Costello M., Washington, D. C., grass paroquet.
Crawford, R., Warren, Ohio, 8 massasaugas.
Curtis, Representative Carl T. of Nebraska, domestic rabbit.*
Cynthia Warner School, Takoma Park, Md., domestic rabbit, 4 Pekin ducks.
Dahl, George, Washington, D. C., eastern robin.
Dargan, Lucas, Washington, D. C., jumping mouse.
Davis, Malcolm, National Zoological Park, Washington, D. C., domestic pigeon.
Davis, Mary, Arlington, Va., mockingbird, 2 blue jays.
De Bruhl, Ben, Washington, D. C., 2 Pekin ducks.
Decker, Robert L., Deale, Md., 14 mallard ducks.
De Santis, Sherwin and Lawrence, Washington, D. C., Pekin duck.
Detwiler, D. T., Richmond, Va., rhesus monkey.

De Zerne, George, Arlington, Va., 2 skunks.
Dillon, Ray A., Washington, D. C., star-nosed mole.
Dog Pound, Washington, D. C., gray fox, raccoon.
Dow, Brenda L., Chevy Chase, Md., 2 Pekin ducks.
Edwards, Nancy, Takoma Park, Md., 3 Cumberland terrapins.
Fergeron, E., Schriever, La., false chameleon.
Ferry, Maxine T., Washington, D. C., 8 domestic rabbits.
Finch, Dick, Arlington, Va., hoary bat.
Foehl, Arthur, Williamstown, N. J., 4 giant land snails.
Fudge, Bill M., Bethesda, Md., osprey or fish hawk.
Geesa, Mrs., Washington, D. C., 2 Pekin ducks.
George Green's Animal and Bird Farm, Bulls Gap, Tenn., box turtle.
Gilbert, Jimmy, Washington, D. C., Pekin duck.
Gilbert, Paul E., Washington, D. C., double yellow-headed parrot.*
Ginsberg, Harry and Jerry, Washington, D. C., pilot snake, water snake.
Glazier, Stephen, Washington, D. C., domestic rabbit.
Golden, Miss Helen, Grand Forks, S. Dak., 14 Indian rock pythons.
Green Acres School, Bethesda, Md., pied grebe.
Hall, Miss Janet, Washington, D. C., Mexican falcon.*
Hanna, Bob, Bethesda, Md., grass paroquet.
Harrison, Mrs. L. H., Washington, D. C., purple grackle.
Harvey, Dr. Verne K., Alexandria, Va., eastern robin.
Heinz, John E., Washington, D. C., Pekin duck.
Hershup, Boyd, Washington, D. C., Pekin duck.
Higgins, J. W., Arlington, Va., snapping turtle.
Hines, W. M., Sr., Arlington, Va., tortoise.
Hoek, Raymond, Fairbanks, Alaska, Arctic fox, 2 snow buntings.
Holmes, Mrs. N. H., Washington, D. C., ring-necked snake.
Horton, Mrs., Washington, D. C., Pekin duck.
Hughes, Charles, Silver Spring, Md., alligator, painted turtle.
Hunter, Jan F., Washington, D. C., 8 Mexican free-tailed bats.
Huppman, Louis R., Baltimore, Md., woolly monkey.*
Ingham, Rex, Ruffin, N. C., raccoon, 2 plains prairie dogs.*
Ingles, O. C., Washington, D. C., muscovy duck.
Jennier, Roy H., National Zoological Park, Washington, D. C., 8 marine toads.
Johnson, John H., Silver Spring, Md., horned grebe.
Johnson, Mrs. W., Chevy Chase, Md., American goldfinch.
Jones, Mrs. Clara, Washington, D. C., black muskrat.
Kaufman, Judy, Greenbelt, Md., blue jay.
Kensey, A. L., Washington, D. C., 2 Pekin ducks.
Kent, Donald, Washington, D. C., opossum.
Kent, Robert R., Washington, D. C., sparrow hawk.
Kley, John A., Washington, D. C., 3 horned lizards.
Knop, Peter, Wood Acres, Md., musk turtle.
Kornfield, Isadore, Washington, D. C., 2 Pekin ducks.
Kroh, Miss Kay, Baltimore, Md., green guenon.
Kuntz, Robert E., Washington, D. C., 3 collared lizards, 6 Zanzibar-Madagascar snails.
Lady, John E., Takoma Park, Md., 3 moscovy ducks.
La Fever, Larry, Arlington, Va., water snake.
Lagarde, B., Frederick, Md., 4 pilot snakes.
Lawler, Mrs. Norton, Washington, D. C., 2 Pekin ducks.
Legel, E. F., Arlington, Va., 7 canaries.
Le Roy, Mrs. H. B., Arlington, Va., Pekin duck.

Lipscomb, George W., Washington, D. C., Pekin duck.
Lohman, K., Alexandria, Va., purple finch.
Long, Mrs. D. E., Washington, D. C., Pekin duck.
Luethje, Harry M., Washington, D. C., sparrow hawk.
Lund, R. J., Washington, D. C., Pekin duck.
Lyons, Miss Nancy, Washington, D. C., 2 Pekin ducks.
Maker, Colin, Washington, D. C., 3 horned lizards.
Mann, O. R., Gaithersburg, Md., 2 domestic geese.
Marknett, K. A., Aldie, Va., red-tailed hawk.
Matthews, Calvin, Washington, D. C., rhesus monkey.*
May, David, Takoma Park, Md., eastern cottontail rabbit.
McCann, Bernice, Washington, D. C., grass paroquet.
Meacham, Miss Ann, Washington, D. C., 2 Pekin ducks.
Meems Bros. & Ward, New York, N. Y., black rhinoceros.*
Megill, W. F., Washington, D. C., mallard duck.
Meyer, F. A., Washington, D. C., tarantula.
Mickey, M. G., Washington, D. C., barn owl.
Miller, Lt. William, Fort Clayton, Canal Zone, white-breasted toucan.
Mills, John, National Zoological Park, 6 pine or fence lizards.
Montminy, Clarence, Washington, D. C., worm snake, 2 pine or fence lizards.
Monzer, Nolan, Garrett Park, Md., 5 opossums.
Morgan, David, Bethesda, Md., barn owl, sparrow hawk,* Cooper's hawk.*
Morris, James, Washington, D. C., American crow.
Murphy, Glen F., Washington, D. C., Pekin duck.
Musser, G., Falls Church, Va., copperhead snake.
Musser, George, Washington, D. C., eastern diamond-backed rattlesnake, hog-nosed snake.
Myers, Miss E. V., Washington, D. C., vervet guenon.*
National Geographic Society, Washington, D. C., pichi ciego mayor.
National Zoological Park Police, Washington, D. C., muskrat.
Natural History Society of Maryland, Baltimore, Md., water moccasin, 2 copperhead snakes.
Nelson, Judy, Alexandria, Va., domestic rabbit.
Nesser, Julius, Chevy Chase, Md., alligator.
Newell, C., Arlington, Va., blue jay.
Newill, Dr. D. S., McConnellsville, Pa., ocellated turkey.
Nigh, Frank, Washington, D. C., gray squirrel.
Oney, Mrs. H., Washington, D. C., tarantula.
Packer, Mrs. D. M., Alexandria, Va., horned lizard.
Paul, Rev. J. Edward, Wilmington, Del., Virginia deer.
Payne, Dorothy, Washington, D. C., screech owl.
Payne, Harold O., Washington, D. C., opossum.
Power, Stacy, Washington, D. C., Philippine macaque.*
Randel, Lt. H., U. S. Army Medical Corps., jaguar, fer-de-lance, water snake, 6 howling monkeys, 3 Panama curassows, 5 Central American boas, 2 sumbadoras or mussurana, 5 tropical rattlesnakes, 16 terrapins.
Reuter, Mrs. L., Washington, D. C., raccoon.
Rhodes, Mrs. I. L., Washington, D. C., gray squirrel.
Rhodes, John, College Heights, Md., Pekin duck.
Roberts, John C., Alexandria, Va., 2 horned lizards.
Roberts, L. W., Washington, D. C., Siamese black-hooded cobra.
Rogers, Raymond, McLean, Va., pilot snake.
Roland, T. J., Washington, D. C., domestic rabbit.
Rucker, Colburn, Arnold, Md., pilot snake.

Schafer, Frederick, Washington, D. C., turkey vulture.
Scherfee, S. H., Los Angeles, Calif., California king snake, California racer snake, Pacific rattlesnake.
Schrieber, W. H., Washington, D. C., mallard duck.
Seay, Charles F., Washington, D. C., Pekin duck.
Shaw, H. L., Baltimore, Md., hamadryad baboon.
Shipley, Mrs. William H., Washington, D. C., Pekin duck.
Sigwald, Mr., Bethesda, Md., hawk.
Simpson, Miss Jacqueline, Washington, D. C., 2 sea horses.
Sloan, Leonard, Washington, D. C., Pekin duck.
Smith, Mrs. Don C., Washington, D. C., 6 golden hamsters.*
Souder, L. B., Arlington, Va., 4 mockingbirds.
Spahn, Carl, Washington, D. C., Pekin duck.
Speaker, Miss Terry, Falls Church, Va., alligator.
Spiegler, Mrs. Paul, Washington, D. C., 2 zebra finches.
Stephenson, Rear Admiral C. S., Washington, D. C., Pekin duck × mallard duck hybrid.*
Stevenson, William R., National Zoological Park, Washington, D. C., mole.
Stoessel, Mrs. Victor, Falls Church, Va., skunk,* Philippine macaque.*
Stohlman, Jack, Chevy Chase, Md., weasel.
Talbert, Mrs. Marian, Washington, D. C., 2 Pekin ducks.
Taylor, Walter, Washington, D. C., Pekin duck.
Thomas, J. L., Jr., Washington, D. C., 2 horned lizards.
U. S. Naval Hospital, Bethesda, Md., rhesus monkey.*
U. S. Naval Medical Research, Bethesda, Md., 104 East African elephant shrews.*
U. S. Naval Second Antarctic Expedition 1947–48, collected by Malcolm Davis of National Zoological Park, Washington, D. C., 8 emperor penguins, 4 adelie penguins, carrier pigeon, douroucouli or owl monkey, brown booby or ganet, honey creeper, pileated tinamou, blue tanager, plain-colored tanager.
Van Horn, Mrs. Lena M., Washington, D. C., double yellow-headed parrot.
Vipond, L. C., Silver Spring, Md., Pekin duck.
Walker, Ernest E., Washington, D. C., 5 golden hamsters.
Wallace, E. E., Landover Hills, Md., sparrow hawk.
Weber, Mrs., Washington, D. C., domestic rabbit.
Welch, Carl, Washington, D. C., skunk.
Wharton, Charles, Avondale Estates, Ga., palm civet,* slender-tailed cloud rat,* monkey-eating eagle,* Philippine serpent eagle,* 26 Mindanao tarsiers,* 7 Philippine tree shrews,* 5 bushy-tailed cloud rats,* 5 reticulated pythons,* 2 monitor lizards,* siren, amphiuma.
Whitmore, Mrs. M. C., Silver Spring, Md., map turtle.
Willard, Miss Carol, Norman, Okla., alligator.
Williams, Clifton R., Washington, D. C., 2 coatimundi.*
Williamson, Mr., Washington, D. C., 8 pilot snakes, 3 water snakes, 4 smooth green snakes.
Wilson, Mr. and Mrs. Ross, Liberia, West Africa, African leopard.
Wilson, Sam, Washington, D. C., eastern robin.
Wilson, Vanez T., Supt., Bear River Migratory Bird Refuge, Brigham, Utah, 6 green-winged teals, 4 baldpates.
Winder, William T., Jr., Alexandria, Va., pilot snake.
Withers, John, Clinton, Md., garter snake.
Woden, Mrs. H. L., Washington, D. C., domestic rabbit.
Wood, Harold, Winchester, Va., domestic pigeon.
Wordford, Mrs., Washington, D. C., alligator.

BIRTHS AND HATCHINGS

MAMMALS

Scientific name	Common name	Number
Ammotragus lervia	Aoudad	4
Ateles geoffroyi vellerosus	Spider monkey	1
Axis axis	Axis deer	1
Bison bison	American bison	1
Bos taurus	British Park cattle	1
Bos taurus	West Highland or Kyloe cattle	1
Camelus bactrianus	Bactrian camel	1
Cephalophus nigrifrons	Black-fronted duiker	1
Cercopithecus aethiops pygerythrus × *C. aethiops sabaeus*	Vervet guenon × green guenon hybrid	1
Cercopithecus aethiops sabaeus	Green guenon	2
Choeropsis liberiensis	Pigmy hippopotamus	1
Cynomys ludovicianus	Plains prairie dog	10
Dama dama	Brown fallow deer	3
Dama dama	White fallow deer	5
Dasyprocta punctata	Speckled agouti	1
Felis concolor	Puma	1
Hemitragus jemlahicus	Tahr	1
Hippopotamus amphibius	Hippopotamus	1
Hylobates agilis × *H. lar pileatus*	Hybrid gibbon	1
Marmota monax	Woodchuck	4
Odocoileus virginianus	Virginia deer	1
Ovis europaea	Mouflon	1
Thalarctos maritimus	Polar bear	2
Thalarctos maritimus × *Ursus middendorffi*	Hybrid bear	4
Vulpes fulva	Red fox	2

BIRDS

Scientific name	Common name	Number
Anas platyrhynchos	Mallard duck	38
Branta canadensis	Canada goose	18
Cairina moschata	Muscovy duck	4
Chenopsis atrata	Black swan	10
Fulica americana	American coot	8
Gallus sp	Fighting fowl	1
Larus novaehollandiae	Silver gull	4
Leucophoyx thula	Snowy egret	1
Nycticorax nycticorax hoactli	Black-crowned night heron	18
Pavo cristatus	Blue peafowl	4
Poephila acuticauda	Long-tailed finch	2
Spheniscus humboldti	Humboldt penguin	1
Taeniopygia castanotis	Zebra finch	3

REPTILES

Scientific name	Common name	Number
Crotalus horridus horridus	Timber rattlesnake	6
Elaphe guttata	Corn snake	7
Epicrates cenchris	Rainboa boa	4

ANIMALS IN THE NATIONAL ZOOLOGICAL PARK, JUNE 30, 1948

MAMMALS

MARSUPIALIA

Scientific name	*Common name*	*Number*
Didelphiidae:		
Didelphis virginiana	Opossum	5
Metachirus nudicaudatus	South American naked-tailed opossum	1
Phalangeridae:		
Petaurus breviceps	Lesser flying phalanger	1
Petaurus sciureus	Australian flying phalanger	2
Macropodidae:		
Dendrolagus inustus	New Guinea tree kangaroo	1

INSECTIVORA

Talpidae:		
Condylura cristata	Star-nosed mole	1
Soricidae:		
Urogale everetti	Philippine tree shrew	2
Erinaceidae:		
Erinaceus europaeus	European hedgehog	4
Macroselididae:		
Elephantulus rufescens	East African elephant shrew	67

CHIROPTERA

Molossidae:		
Tadarida mexicana	Free-tailed bat	2

CARNIVORA

Felidae:		
Felis chaus	Jungle cat	1
Felis concolor	Puma	4
Felis concolor patagonica	Patagonian puma	1
Felis concolor × *F. c. patagonica*	Hybrid North American × South American puma	4
Felis leo	Lion	3
Felis onca	Jaguar	4
	Black jaguar	1
Felis pardalis	Ocelot	2
Felis pardus	Indian leopard	1
	Black Indian leopard	2
Felis pardus	African leopard	1
Felis temminckii	Golden cat	1
Felis tigris	Bengal tiger	2
Felis tigris longipilis	Siberian tiger	1
Felis tigris sumatrae	Sumatran tiger	2
Herpailurus yaguarondi	Eyra or yaguarondi	1
Lynx rufus	Eastern bob cat	1
Oncifelis geoffroyi	Geoffroy's cat	3
Oncilla pardinoides	Lesser tiger cat	1

Scientific name	Common name	Number
Viverridae:		
Arctictis binturong	Binturong	1
Civettictis civetta	African civet	1
Myonax sanguineus	Dwarf civet	1
Nandinia binotata	African palm civet	1
Paradoxurus hermaphroditus	Small-toothed palm civet	2
Hyaenidae:		
Crocuta crocuta germinans	East African spotted hyena	2
Canidae:		
Alopex lagopus	Arctic fox	1
Canis dingo	Dingo	2
Canis latrans	Coyote	1
Canis lupus nubilus	Plains wolf	1
Cuon javanicus sumatrensis	Sumatran wild dog	1
Fennecus zerda	Fennec fox	1
Nyctereutes procyonoides	Raccoon dog	1
Urocyon cinereoargenteus	Gray fox	8
Vulpes fulva	Red fox	11
Procyonidae:		
Bassaricyon sp	Cuzumbie	2
Nasua narica	Coatimundi	10
Nasua nasua	Red coatimundi	1
Nasua nelsoni	Nelson's coatimundi	1
Potos flavus	Kinkajou	6
Procyon lotor	Raccoon	8
	Black raccoon	3
	Raccoon (albino)	1
Bassariscidae:		
Bassariscus astutus	Ring-tail or cacomistle	1
Mustelidae:		
Grisonella huronax	Grison	1
Lutra canadensis vaga	Florida otter	1
Martes (Lamprogale) flavigula henricii	Asiatic marten	1
Meles meles leptorynchus	Chinese badger	1
Mellivora capensis	Ratel	1
Mephitis mephitis nigra	Skunk	1
Mustela eversmanni	Ferret	7
Mustela frenata noveboracensis	Weasel	1
Taxidea taxus	American badger	1
Tayra barbara barbara	White tayra	2
Tayra barbara senilis	Gray-headed tayra	2
Ursidae:		
Euarctos americanus	Black bear	2
Euarctos thibetanus	Himalayan bear	1
Helarctos malayanus	Malay or sun bear	1
Melursus ursinus	Sloth bear	1
Thalarctos maritimus	Polar bear	2
Thalarctos maritimus × *Ursus middendorffi*	Hybrid bear	4
Tremarctos ornatus	Spectacled bear	1
Ursus arctos	European brown bear	1
Ursus arctos occidentalis	Syrian brown bear	2
Ursus gyas	Alaskan Peninsula bear	4
Ursus middendorffi	Kodiak bear	3
Ursus sitkensis	Sitka brown bear	3

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PINNIPEDIA

Scientific name	Common name	Number
Otariidae:		
Zalophus californianus	Sea lion	2
Procidae:		
Phoca vitulina richardii	Pacific harbor seal	2

PRIMATES

Scientific name	Common name	Number
Lemuridae:		
Lemur macacao	Acoumba lemur	2
Lemur mongoz	Mongoz lemur	2
Tarsius carbonarius	Mindanao tarsiers	3
Callitrichidae:		
Leontocebus rosalia	Silky or lion-headed marmoset	2
Cebidae:		
Aotus trivirgatus	Dourouculi or owl monkey	6
Ateles geoffroyi vellerosus	Spider monkey	2
Cebus apella	Gray capuchin	3
Cebus capucinus	White-throated capuchin	4
Cebus fatuellus	Weeping capuchin	3
Cercopithecidae:		
Cercocebus aterrimus	Black-crested mangabey	1
Cercocebus fuliginosus	Sooty mangabey	2
Cercocebus torquatus lunulatus	White-crowned mangabey	1
Cercopithecus aethiops pygerythrus	Vervet guenon	1
Cercopithecus aethiops sabaeus	Green guenon	11
Cercopithecus aethiops sabaeus × *C. a. pygerythrus*	Hybrid green guenon × vervet guenon	3
Cercopithecus cephus	Moustached guenon	2
Cercopithecus diana	Diana monkey	3
Cercopithecus diana roloway	Roloway monkey	1
Cercopithecus neglectus	De Brazza's guenon	1
Cercopithecus nictitans petaurista	Lesser white-nosed guenon	2
Cercopithecus preussi	Preussi's guenon	1
Erythrocebus patas	Patas monkey	1
Gymnopyga maurus	Moor monkey	1
Macaca irus	Crab-eating macaque	1
Macaca irus mordax	Javan macaque	4
Macaca lasiotis	Chinese macaque	1
Macaca mulatta	Rhesus monkey	13
Macaca nemestrina	Pig-tailed monkey	1
Macaca philippinensis	Philippine macaque	4
Macaca silenus	Wanderoo monkey	2
Macaca sinica	Toque or bonnet monkey	1
Macaca speciosa	Red-faced macaque	1
Papio porcarius	Chacma baboon	1
Hylobatidae:		
Hylobates agilis	Sumatran gibbon	1
Hylobates agilis × *H. lar pileatus*	Hybrid gibbon	1
Hylobates hoolock	Hoolock gibbon	1
Hylobates lar pileatus	Black-capped gibbon	1
Symphalangus syndactylus	Siamang gibbon	1

RODENTIA

Scientific name	Common name	Number
Sciuridae:		
Citellus beecheyi douglasii	Douglas ground squirrel	2
Cynomys ludovicianus	Plains prairie dog	66
Funisciurus leucostigma	West African bush squirrel	2
Glaucomys volans	Flying squirrel	6
Marmota monax	Woodchuck or ground hog	4
Sciurus stramineus	South American gray squirrel	2
Tamias striatus	Eastern chipmunk	1
Tamiasciurus hudsonicus	Red squirrel	1
Heteromyidae:		
Dipodomys ordii	Ord kangaroo rat	2
Cricetidae:		
Mesocricetus auratus	Golden hamster	30
Microtus pennsylvanicus	Meadow mouse	6
Muridae:		
Crateromys schadenbergi	Bushy-tailed cloud rat	1
Meriones unguiculatus	Mongolian gerbil	1
Mus musculus	White and other domestic mice	10
Ondatra zibethicus	Muskrat	7
Oryzomys palustris	Rice rat	4
Phloeomys cumingi	Slender-tailed cloud rat	3
Rattus norvegicus	Hooded laboratory rat	21
Hystricidae:		
Acanthion brachyurum	Malay porcupine	3
Atherurus africanus	West African brush-tailed porcupine	1
Myocastoridae:		
Myocastor coypus	Coypu	3
Capromyidae:		
Capromys pilorides	Hutia	2
Dasyproctidae:		
Cuniculus paca	Paca	2
Dasyprocta prymnolopha	Agouti	1
Dasyprocta punctata	Speckled agouti	1
Chinchillidae:		
Chinchilla chinchilla	Chinchilla	4
Lagidium viscaccia	Peruvian viscacha	5
Caviidae:		
Cavia porcellus	Guinea pig	2
Dolichotis patagona	Patagonian cavy	1

LAGOMORPHA

Scientific name	Common name	Number
Leporidae:		
Oryctolagus cuniculus	Domestic rabbit	1
Sulvilagus floridanus	Cottontail rabbit	1

ARTIODACTYLA

Scientific name	Common name	Number
Bovidae:		
Ammotragus lervia	Aoudad	21
Bibos gaurus	Gaur	3
Bison bison	American bison	13
	Albino bison	1

Scientific name	*Common name*	*Number*
Bovidae—Continued		
Bos indicus	Zebu	3
Bos taurus	Domestic cow (Jersey)	1
Bos taurus	West Highland or Kyloe cattle	4
Bos taurus	British Park cattle	6
Bubalus bubalis	Water buffalo	2
Capra sibirica	Ibex	1
Cephalophus maxwellii	Maxwell's duiker	1
Cephalophus niger	Black duiker	1
Cephalophus nigrifrons	Black-fronted duiker	3
Hemitragus jemlahicus	Tahr	6
Limnotragus spekii	Sitatunga	1
Oryx leucoryx	Arabian oryx	1
Ovis aries	Domestic sheep	1
Ovis europaea	Mouflon	3
Poephagus grunniens	Yak	5
Pseudois nayaur	Bharal or blue sheep	1
Syncerus caffer	African buffalo	2
Taurotragus oryx	Eland	4
Cervidae:		
Axis axis	Axis deer	4
Cervus canadensis	American elk	4
Cervus elaphus	Red deer	2
Cervus nippon	Japanese deer	5
Cervus nippon manchuricus	Dybowsky deer	2
Dama dama	Fallow deer	13
	White fallow deer	16
Odocoileus virginianus	Virginia deer	8
Giraffidae:		
Giraffa camelopardalis	Nubian giraffe	4
Giraffa reticulata	Reticulated giraffe	1
Camelidae:		
Camelus bactrianus	Bactrian camel	3
Camelus dromedarius	Single-humped camel	3
Lama glama	Llama	1
Lama glama guanico	Guanaco	3
Lama pacos	Alpaca	2
Vicugna vicugna	Vicuña	1
Tayassuidae:		
Pecari angulatus	Collared peccary	1
Suidae:		
Babirussa babyrussa	Babirussa	1
Phacochoerus aethiopicus aeliani	East African wart hog	2
Sus scrofa	European wild boar	2
Hippopotamidae:		
Choeropsis liberiensis	Pigmy hippopotamus	6
Hippopotamus amphibius	Hippopotamus	2
	PERISSODACTYLA	
Equidae:		
Equus burchellii antiquorum	Chapman's zebra	2
Equus kiang	Asiatic wild ass or kiang	1
Equus onager	Onager	1
Equus przewalskii	Mongolian wild horse	3
Equus zebra	Mountain zebra	1

Scientific name	Common name	Number
Tapiridae:		
Acrocodia indica	Asiatic tapir	2
Rhinocerotidae:		
Diceros bicornis	Black rhinoceros	1
Rhinoceros unicornis	Great Indian one-horned rhinoceros	1
PROBOSCIDEA		
Elephantidae:		
Loxodonta africana oxyotis	African elephant	1
EDENTATA		
Dasypodidae:		
Chaetophractus villosus	Hairy armadillo	1
Euphractus sexcinctus	Six-banded armadillo	1
Myrmecophagidae:		
Myrmecophaga tridactyla	Giant anteater	1
BIRDS		
STRUTHIONIFORMES		
Struthionidae:		
Struthio camelus	Ostrich	1
RHEIFORMES		
Rheidae:		
Rhea americana	Common rhea	3
CASUARIFORMES		
Casuariidae:		
Casuarius casuarius aruensis	Aru cassowary	1
Casuarius uniappendiculatus occipitalis	Island cassowary	1
Casuarius uniappendiculatus uniappendiculatus	One-wattled cassowary	1
Dromiceiidae:		
Dromiceius novaehollandiae	Common emu	2
SPHENISCIFORMES		
Spheniscidae:		
Aptenodytes forsteri	Emperor penguin	2
Eudyptes chrysolophus	Macaroni penquin	2
Eudyptes cristatus	Rock-hopper penguin	1
Spheniscus demersus	Jackass penguin	3
Spheniscus humboldti	Humboldt penguin	2
Spheniscus magellanicus	Magellan penguin	2
PELECANIFORMES		
Pelecanidae:		
Pelecanus erythrorhynchus	White pelican	4
Pelecanus occidentalis californicus	California brown pelican	2
Pelecanus occidentalis occidentalis	Brown pelican	2
Pelecanus roseus	Rose-colored pelican	3
Sulidae:		
Sula leucogaster	Peruvian booby	1
Phalacrocoracidae:		
Phalacrocorax auritus albociliatus	Farallon cormorant	1

CICONIIFORMES

Scientific name	Common name	Number
Ardeidae:		
Ardea herodias	Great blue heron	2
Hydranassa tricolor ruficollis	Louisiana heron	1
Leucophoyx thula	Snowy egret	5
Notophoyx novaehollandiae	White-faced heron	1
Nycticorax nycticorax hoactli	Black-crowned night heron	35
Cochleariidae:		
Cochlearius cochlearius	Boat-bill heron	1
Ciconiidae:		
Dissoura episcopus	Woolly-necked stork	1
Ibis cinereus	Malay stork	2
Jabiru mycteria	Jabiru	2
Leptoptilus crumeniferus	Marabou	1
Leptoptilus dubius	Indian adjutant	1
Leptoptilus javanicus	Lesser adjutant	2
Mycteria americana	Wood ibis	1
Threskiornithidae:		
Ajaia ajaja	Roseate spoonbill	4
Guara alba	White ibis	8
Guara alba × G. rubra	Hybrid white and scarlet ibis	1
Guara rubra	Scarlet ibis	1
Threskiornis melanocephala	Black-headed ibis	4
Threskiornis spinicollis	Straw-necked ibis	2
Phoenicopteridae:		
Phoenicopterus antiquorum	Old world flamingo	6
Phoenicopterus chilensis	Chilean flamingo	2
Phoenicopterus ruber	Cuban flamingo	1

ANSERIFORMES

Scientific name	Common name	Number
Anhimidae:		
Chauna chavaria	White-cheeked screamer	1
Chauna torquata	Crested screamer	5
Anatidae:		
Aix sponsa	Wood duck	4
Anas bahamensis	Bahama pintail	2
Anas brasiliensis	Brazilian teal	2
Anas domestica	Pekin duck	42
Anas platyrhynchos	Mallard duck	61
	White mallard duck	6
Anas rubripes	Black duck	5
Anser albifrons	American white-fronted goose	1
Anser cinereus domestica	Toulouse goose	4
Anseranus semipalmata	Australian pied goose	2
Aythya sp	Hybrid duck	1
Aythya valisineria	Canvasback duck	2
Branta canadensis	Canada goose	17
Branta canadensis occidentalis	White-cheeked goose	21
Branta canadensis × Chen caerulescens	Hybrid Canada goose × blue goose	2
Branta hutchinisii	Hutchin's goose	3
Branta hutchinsii minima	Cackling goose	3

Scientific name	Common name	Number
Anatidae—Continued		
Cairina moschata	Muscovy duck	9
Cereopsis novaehollandiae	Cape Barren goose	1
Chen atlantica	Snow goose	3
Chen caerulescens	Blue goose	3
Chenopis atrata	Black swan	11
Chloephaga leucoptera	Magellan goose	1
Coscoroba coscoroba	Coscoroba	2
Cygnopsis cygnoides	Domestic goose	1
Cygnus columbianus	Whistling swan	2
Cygnus melancoriphus	Black-necked swan	1
Dafila acuta	Pintail	8
Dafila spinicauda	Chilean pintail	1
Dendrocygna autumnalis	Black-bellied tree duck	3
Dendrocygna viduata	White-faced tree duck	3
Dendronessa galericulata	Mandarin duck	1
Mareca americana	Baldpate	1
Marila affinis	Lesser scaup	1
Marila collaris	Ring-necked duck	1
Metopiana peposaca	Rosy-billed pouchard	3
Nettion carolinense	Green-winged teal	3
Nettion formosum	Baikal teal	2
Philacte canagica	Emperor goose	2
Querquedula discors	Blue-winged teal	2
FALCONIFORMES		
Cathartidae:		
Cathartes aura	Turkey vulture	1
Coragyps atratus	Black vulture	3
Sarcoramphus papa	King vulture	2
Vultur gryphus	Andean condor	1
Sagittariidae:		
Sagittarius serpentarius	Secretary bird	2
Accipitridae:		
Buteo jamaicensis	Red-tailed hawk	4
Buteo lineatus lineatus	Red-shouldered hawk	1
Buteo melanoleucus	South American buzzard eagle	2
Buteo platypterus	Broad-winged hawk	1
Buteo poecilochrous	Red-backed buzzard	2
Buteo swainsoni	Swainson's hawk	1
Gypohierax angolensis	Fish-eating vulture	1
Gyps fulvus	Griffon vulture	1
Gyps rueppelli	Ruppell's vulture	2
Haliaeetus leucocephalus	Bald eagle	5
Haliaeetus leucogaster	White-breasted sea eagle	1
Haliastur indus	Brahminy kite	4
Harpia harpya	Harpy eagle	2
Milvago chimango	Chimango	3
Milvus migrans parasitus	African yellow-billed kite	2
Parabuteo unicinctus	One-banded hawk	1
Pithecophaga jefferyi	Monkey-eating eagle	1
Sarcogyps calvus	Indian Pondicherry vulture	1
Spiziastur melanoleucus	Black and white hawk eagle	1

Scientific name	*Common name*	*Number*
Falconidae:		
Daptrius americanus	Red-throated caracara	3
Falco mexicanus	Prairie falcon	1
Falco peregrinus anatum	Duck hawk	1
Falco sparverius	Sparrow hawk	6
Polyborus plancus	South American caracara	1

GALLIFORMES

Cracidae:		
Crax fasciolata	Crested curassow	2
Crax rubra	Panama curassow	1
Crax sclateri	Sclater's curassow	1
Mitu mitu	Razor-billed curassow	1
Phasianidae:		
Argusianus argus	Argus pheasant	2
Catreus wallichii	Cheer pheasant	1
Chrysolophus amherstiae	Lady Amherst's pheasant	1
Chrysolophus pictus	Golden pheasant	4
Crossoptilon auritum	Blue-eared pheasant	1
Gallus sp	Bantam chicken	4
Gallus sp	Oriental silky bantam fowl	4
Gallus sp	Fighting fowl	3
Gallus gallus	Red jungle fowl	11
Gallus gallus	Hybrid red jungle fowl × bantam fowl	1
Gallus lafayetii	Ceylonese jungle fowl	1
Gallus sonneratii	Gray jungle fowl	1
Gennaeus albocristatus	White-crested kaleege	1
Gennaeus leucomelanus	Nepal kaleege	2
Gennaeus nycthemerus	Silver pheasant	3
Hierophasis swinhoii	Swinhoe's pheasant	2
Pavo cristatus	Peafowl	9
Phasianus torquatus	Ring-necked pheasant	2
Polyplectron napoleonis	Palawan peacock pheasant	1
Syrmaticus reevesi	Reeve's pheasant	2
Numididae:		
Acryllium vulturinum	Vulturine guinea fowl	1
Numida sp	Guinea fowl	2
Meleagrididae:		
Agriocharis ocellata	Ocellated turkey	4
Meleagris gallopavo	Wild turkey	2

GRUIFORMES

Gruidae:		
Anthropoides virgo	Demoiselle crane	2
Balearica pavonina	West African crowned crane	2
Balearica regulorum gibbericeps	East African crowned crane	1
Grus leucauchen	White-naped crane	1
Grus leucogeranus	Siberian crane	2
Psophiidae:		
Psophia leucoptera	White-backed trumpeter	2

Scientific name	*Common name*	*Number*
Rallidae:		
Amaurornis phoenicurus	White-breasted rail	1
Armides cajanea	Wood rail	2
Fulica americana	American coot	6
Gallinula chloropus cachinnans	Florida gallinule	1
Cariamidae:		
Cariama cristata	Cariama or seriema	2
CHARADRIIFORMES		
Scolopacidae:		
Philohela minor	Woodcock	1
Recurvirostridae:		
Himantopus mexicanus	Black-necked stilt	2
Burhinidae:		
Burhinus bistriatus	South American thick-knee	2
Haematopodidae:		
Haematopus ostralegus	European oyster catcher	1
Charadriidae:		
Belanopterus chilensis	Chilean lapwing	2
Laridae:		
Larus argentatus	Herring gull	2
Larus delawarensis	Ring-billed gull	1
Larus dominicanus	Kelp gull	2
Larus novaehollandiae	Silver gull	8
COLUMBIFORMES		
Columbidae:		
Columba livia	Domestic pigeon	15
Ducula aenea	Green imperial pigeon	1
Ducula paulina	Celebian imperial pigeon	2
Gallicolumba luzonica	Bleeding-heart dove	1
Gallicolumba luzonica × *Turtur risorius*	Bleeding-heart dove × ring-necked dove hybrid	1
Geopelia cuneata	Diamond dove	1
Goura victoria	Victoria crowned pigeon	1
Streptopelia tranquebarica	Blue-headed ring dove	2
Turtur risorius	Ring-necked dove	32
Zenaida auriculata	South America mourning dove	1
Zenaida macroura	Mourning dove	2
PSITTACIFORMES		
Psittacidae:		
Agapornis lilianae	Red-faced love bird	1
Agapornis roseicollis	Rosy-faced love bird	2
Amazona aestiva	Blue-fronted parrot	1
Amazona auropalliata	Yellow-naped parrot	3
Amazona ochrocephala	Yellow-headed parrot	3
Amazona oratrix	Double yellow-headed parrot	6
Anodorhynchus hyacinthinus	Hyacinthine macaw	1
Ara ararauna	Yellow and blue macaw	1
Ara macao	Red, blue, and yellow macaw	4

Scientific name	*Common name*	*Number*
Psittacidae—Continued		
Aratinga euops	Cuban conure	1
Aratinga pertinax	Gray-headed conure	1
Calyptorhynchus magnificus	Banksian cockatoo	1
Ducorpsis sanguineus	Bare-eyed cockatoo	1
Kakatoe alba	White cockatoo	2
Kakotoe ducrops	Solomon Islands cockatoo	2
Kakatoe galerita	Large sulphur-crested cockatoo	3
Kakatoe leadbeateri	Leadbeater's cockatoo	1
Kakatoe moluccensis	Great red-crested cockatoo	1
Kakatoe sulphurea	Lesser sulphur-crested cockatoo	1
Lorius domicella	Rajah lory	2
Lorius garrulus	Red lory	1
Melopsittacus undulatus	Grass paroquet	23
Nestor notabilis	Kea	1
Nymphicus hollandicus	Cockatiel	2
Psittacula eupatria	Red-shouldered paroquet	1
Psittacula krameri	Kramer's paroquet	1
Psittacula longicauda	Long-tailed paroquet	1
CUCULIFORMES		
Musophagidae:		
Touraco corythaix	South African turaco	2
Touraco donaldsoni	Donaldson's turaco	1
STRIGIFORMES		
Tytonidae:		
Tyto alba pratincola	Barn owl	3
Strigidae:		
Bubo virginianus	Great horned owl	9
Ketupa ketupa	Malay fishing owl	1
Otus asio	Screech owl	3
Strix varia varia	Barred owl	11
TROGONIFORMES		
Trogonidae:		
Pharomachrus mocino	Quetzal	1
CORACIIFORMES		
Alcedinidae:		
Dacelo gigas	Kookaburra	2
Coraciidae:		
Anthracoceros coronatus	Pied hornbill	2
Tockus birostris	Gray hornbill	1
Momotidae:		
Momotus lessoni	Motmot	1
PICIFORMES		
Capitonidae:		
Megalaima asiatica	Blue-throated barbet	1

Scientific name	*Common name*	*Number*
Ramphastidae:		
Aulacorhynchus sulcatus sulcatus	Groove-billed toucanet	1
Pteroglossus aracari	Black-necked aracari	2
Pteroglossus torquatus	Aracari toucan	1
Ramphastos ariel	Ariel toucan	2
Ramphastos carinatus	Sulphur-breasted toucan	3
Ramphastos culminatus	White-breasted toucan	1
Ramphastos piscivorus	Toco toucan	1
PASSERIFORMES		
Cotingidae:		
Rupicola rupicola	Cock-of-the-rock	2
Dicruridae:		
Dissemurus paradiseus	Giant racquet-tailed drongo	5
Corvidae:		
Callocitta formosa	Mexican jay	1
Cissilopha yucatanica	Yucatan blue jay	1
Corvus brachyrhynchos	American crow	4
Corvus corax principalis	Northern raven	2
Corvus cornix	Hooded crow	1
Corvus cryptoleucus	White-necked raven	1
Corvus insolens	Indian crow	2
Cyanocitta cristata	Blue jay	7
Cyanocorax chrysops	Urraca jay	1
Cyanopica cyana	Azure-winged pie	1
Garrulus lanceolatus	Black-throated jay	1
Gymnorhina hypoleuca	White-backed piping crow	1
Pica nuttalli	Yellow-billed magpie	1
Pica pica hudsonica	American magpie	2
Urocissa caerulea	Formosan red-billed pie	2
Paradiseidae:		
Ailuroedus crassirostris	Australian catbird	1
Ptilonorhynchus violaceus	Satin bowerbird	1
Timaliidae:		
Garrulax bicolor	White-headed laughing thrush	2
Garrulax pectoralis picticollis	Chinese collared laughing thrush	1
Pycnonotidae:		
Heterophasia capistratra	Black-headed sibia	4
Pycnonotus analis	Yellow-vented bulbul	1
Pycnonotus leucogenys	White-cheeked bulbul	2
Mimidae:		
Mimus polyglottos	Mockingbird	4
Mimus polyglottos leucopterus	Western mockingbird	1
Turdidae:		
Geokichla citrina	Orange-headed ground thrush	2
Platycichla flavipes	Yellow-footed thrush	1
Turdus grayi	Bonaparte's thrush	1
Turdus migratorius	Eastern robin	4

Scientific name	*Common name*	*Number*
Sturnidae:		
Galeopsar salvadorii	Crested starling	1
Gracula religiosa	Hill mynah	1
Graculipica melanoptera	White starling	1
Lamprocolius splendens	Splendid glossy starling	4
Lamprotornis australis	Burchelli's glossy starling	4
Sturnia malabarica	Pied mynah	1
Sturnus vulgarus	Starling	1
Ploceidae:		
Aidemosyne cantans	Tawny waxbill	6
Aidemosyne malabarica	Indian silver-bill	2
Aidemosyne modesta	Plum-head finch	2
Alisteranus cinctus	Parson finch	2
Amadina fasciata	Cut-throat weaver finch	7
Cayleyna picta	Painted finch	1
Diatropura procne	Giant whydah	2
Estrilda astrild	Red-eared waxbill	8
Estrilda cinerea	Common waxbill	16
Euplectes franciscana	Bishop weaver	5
Hypochera ultramarina	Combasou or indigo bird	1
Lagonosticta senegalla	African fire finch	2
Lonchura leucogastroides	Bengallee finch	2
Munia maja	White-headed munia	2
Munia malacca	Black-throated munia	1
Munia oryzivora	Java sparrow	5
Munia punctulata	Spice finch	3
Neopoephila personata	Masked finch	2
Ploceus baya	Baya weaver	2
Ploceus intermedius	Black-cheeked weaver	2
Ploceus vitellinus	Vitelline masked weaver	7
Poephila cuticauda	Long-tailed finch	1
Poephila gouldiae	Gouldian finch	1
Quelea quelea	Red-billed weaver	5
Sporaeginthus melopodus	Orange-cheeked waxbill	10
Steganua paradisea	Paradise whydah	10
Stictoptera bichenovii	Binchenov's finch	1
Taeniopygia castanotis	Zebra finch	10
Uraeointhus bengalus	Cordon bleu finch	10
Coerebidae:		
Cyanerpes cyaneus	Blue honey creeper	15
Icteridae:		
Agelaius assimilis	Cuban red-winged blackbird	2
Amblyrhamphus holosericeus	Scarlet-headed blackbird	1
Cassiculus melanicterus	Mexican cacique	1
Gymnomystax mexicanus	Giant oriole	1
Icterus bullocki	Bullock's troupial	1
Molothrus bonariensis	Shiny cowbird	1
Notiopsar curaesus	Chilean blackbird	2
Quiscalis quiscula	Purple grackle	2
Trupialis defilippi	Military starling	4
Xanthocephalus xanthocephalus	Yellow-headed blackbird	2

Scientific name	Common name	Number
Thraupidae:		
Calospiza inornata languens	Plain-colored tanager	1
Ramphocelus carbo	Silver-beaked tanager	2
Ramphocelus dimidiatus	Crimson tanager	2
Ramphocelus flammigerus	Yellow tanager	2
Ramphocelus passerini	Passerini tanager	1
Tanagra darwini	Darwin's tanager	2
Thraupis cana	Blue tanager	3
Fringillidae:		
Aegintha temporalis	Sydney waxbill	12
Carpodacus mexicanus	Mexican house finch	6
Carpodacus purpureus californicus	California purple finch	1
Coryphospingus cucullatus	Red-crested finch	1
Cyanocompsa argentina	Argentine blue grosbeak	2
Diuca diuca	Diuca finch	1
Lophospingus pusillus	Black-crested finch	2
Melopyrrha nigra	Cuban bullfinch	2
Melospiza melodia	Song sparrow	2
Paroaria cucullata	Brazilian cardinal	2
Paroaria gularis nigro-genis	Black-eared cardinal	3
Passerella iliaca	Fox sparrow	1
Passerina amoena	Lazuli bunting	1
Passerina cyanea	Indigo bunting	2
Passerina leclancheri	Leclancher's bunting	2
Passerina versicolor	Blue bunting	1
Pheucticus aureoventris	Black and yellow grosbeak	2
Phrygilus alaudinus	Chilean lark finch	1
Phrygilus fruticeti	Mourning finch	4
Phrygilus gayi	Gay's gray-headed finch	1
Plectrophenax nivalis	Snow bunting	2
Poospiza torquata	Ringed warbling finch	2
Richmondina cardinalis	Cardinal	3
Serinus canarius	Canary	13
Serinus canarius × *Carduelis mexicana*	Canary × siskin hybrid	2
Serinus icterus	Green singing finch	1
Sicalis flaveola	Mysto finch	1
Sicalis luteola	Saffron finch	3
Sicalis minor	Lesser yellow finch	4
Spinus tristis	American gold finch	1
Spinus uropygialis	Chilean siskin	1
Sporophila aurita	Hick's seed-eater	1
Sporophila gutturalis	Yellow-billed seed-eater	2
Sporophila melanocephala	Black-headed seed-eater	2
Tiaris olivacea	Mexican grassquit	2
Volatinia jacarini	Blue-black grassquit	1
Zonotrichia albicollis	White-throated sparrow	2
Zonotrichia capensis	Chingolo	4

REPTILES

LORICATA

Scientific name	Common name	Number
Crocodylidae:		
Alligator mississipiensis	Alligator	29
Alligator sinensis	Chinese alligator	3
Caiman latirostris	Broad-snouted caiman	1
Caiman sclerops	Spectacled caiman	3
Crocodylus acutus	American crocodile	3
Crocodylus cataphractus	Narrow-nosed crocodile	1
Crocodylus niloticus	African crocodile	2
Crocodylus palustris	"Toad" crocodile	2
Crocodylus porosus	Salt-water crocodile	1
Crocodylus rhombifer	Cuban crocodile	1
Osteolaemus tetraspis	Broad-nosed crocodile	3
Lacertidae:		
Lacerta muralis	Wall lizard	2
Lacerta ocellata	Eyed lizard	2
Iguanidae:		
Anolis carolinensis	False chameleon	125
Basiliscus vittatus	Basilisk	2
Phrynosoma cornutum	Horned lizard	6
Sceloporus undulatus	Pine or fence lizard	6
Anguidae:		
Ophisaurus ventralis	Legless lizard or glass "snake"	1
Agamidae:		
Uromastix acanthinurus	North African spiny-tailed lizard	2
Helodermatidae:		
Heloderma horridum	Mexican beaded lizard	2
Heloderma suspectum	Gila monster	6
Teiidae:		
Tupinambis nigropunctatus	Black tegu	5
Scincidae:		
Eumeces fasciatus	Blue-tailed skink	2
Tiliqua scincoides	Blue-tongued lizard	1
Varanidae:		
Varanus sp	Philippine monitor	1
Varanus komodoensis	Komodo dragon	1
Varanus niloticus	African monitor	2
Varanus salvator	Sumatran monitor	3
Zonuridae:		
Zonurus giganteus	African spiny lizard	5

SERPENTES

Boidae:		
Constrictor constrictor	Boa constrictor	1
Constrictor imperator	Central American boa	10
Constrictor mexicanus	Southern boa	1
Epicrates cenchris	Rainbow boa	13
Epicrates crassus	Salamanta	1
Epicrates striatus	Haitian boa	1

Scientific name	*Common name*	*Number*
Boidae—Continued		
Eunectes murinus	Anaconda	1
Python molurus	Indian rock python	17
Python regius	Ball python	1
Python reticulatus	Regal python	5
Colubridae:		
Boiga blandingi	Brown tree snake	1
Carphophis amoena	Worm snake	1
Coluber constrictor mormon	California racer	1
Diadophis punctatus	Ring-necked snake	2
Duberria cana	South African mole snake	2
Elaphe guttata	Corn snake	2
Elaphe obsoleta	Pilot snake	7
Elaphe quadrivittata	Chicken snake	1
Heterodon contortrix	Hog-nosed snake	1
Lampropeltis getulus boylii	Boyle's king snake	3
Lampropeltis triangulum triangulum	Milk snake or spotted adder	1
Masticophis taeniatus	Lined Mexican racer	1
Natrix sp	Water snake	12
Natrix piscator	Checkered keel back	3
Natrix sipedon	Banded water snake	3
Oxybelis acuminatus	Pike-head snake	1
Ptyas mucosus	Indian rat snake	1
Storeria dekayi	De Kay's snake	2
Thamnophis macrostemma	Mexican garter snake	1
Thamnophis ordinoides	Western garter snake	1
Thamnophis sirtalis	Garter snake	7
Thrasops jacksonii	Black tree snake	1
Elapidae:		
Dendroaspis viridis	Green mamba	1
Naja melanoleuca	West African cobra	2
Viperidae:		
Vipera berus	European viper	2
Crotalidae:		
Agkistrodon mokeson	Copperhead snake	3
Agkistrodon piscivorus	Cotton-mouth moccasin	2
Bothrops lanceolatus	Fer de-lance	1
Crotalus atrox	Texas diamond-backed rattlesnake	2
Crotalus horridus	Eastern diamond-backed rattlesnake	6
Crotalus horridus horridus	Timber rattlesnake	1
Crotalus oreganus	Pacific rattlesnake	1

TESTUDINATA

Chelydidae:		
Batrachemys nasuta	South American side-necked turtle	2
Hydraspis sp	Cágado or South American snake-necked turtle	1
Hydromedusa tectifera	South American snake-necked turtle	16
Platemys platycephala	Flat-headed turtle	1

Scientific name	*Common name*	*Number*
Kinosternidae:		
Kinosternon subrubrum	Mud or musk turtle	5
Sternotherus odoratus	Mud or musk turtle	4
Chelydridae:		
Chelydra serpentina	Snapping turtle	4
Macrochelys temminckii	Alligator snapping turtle	1
Testudinidae:		
Batagur baska	Indian fresh-water turtle	1
Chrysemys picta	Painted turtle	7
Clemmys guttata	Spotted turtle	6
Clemmys insculpta	Wood turtle	3
Cyclemys amboinensis	Kura kura box turtle	1
Graphtemys barbouri	Barbour's turtle	6
Malaclemys centrata	Diamond-backed turtle	5
Pelomedusa galeata	Common African water tortoise	1
Pseudemys concinna	Cooter	1
Pseudemys elegans	Mobile terrapin	12
Pseudemys ornata subsp	Central American terrapin	6
Pseudemys rugosa	Cuban terrapin	1
Terrapene carolina	Box turtle	50
Terrapene major	Florida box turtle	4
Testudo ephippium	Duncan Island tortoise	1
Testudo hoodensis	Hood Island tortoise	2
Testudo tabulata	South American tortoise	1
Testudo tornieri	Soft-shelled land tortoise	1
Testudo vicina	Albemarle Island tortoise	5
Trionychidae:		
Amyda ferox	Soft-shelled turtle	6
Amyda triunguis	West African soft-shelled turtle	1

AMPHIBIA

CAUDATA

Salamandridae:		
Triturus cristatus danubialis	Crested newt	12
Triturus pyrrhogaster	Red Japanese salamander	2
Triturus torosus	Giant newt	5
Triturus vulgaris	Common European salamander	3
Amphiumidae:		
Amphiuma means	Congo eel	1
Ambystomidae:		
Ambystoma opacum	Marbled salamander	1
Ambystoma tigrinum	Tiger salamander	30
Cryptobranchidae:		
Megalobatrachus japonicus	Giant Japanese salamander	1
Sirenidae:		
Siren lacertina	Sirene	1

SALIENTIA

Scientific name	Common name	Number
Dendrobatidae:		
Atelopus varius cruciger	Yellow atelopus	20
Dendrobates auratus	Arrow-poison frog	52
Dendrobates wittei	Red and black frog	1
Bufonidae:		
Bufo americanus	Common toad	1
Bufo empusus	Sapo de concha	4
Bufo marinus	Marine toad	10
Bufo peltacephalus	Cuban giant toad	2
Discoglossidae:		
Bombina bombina	Red-bellied toad	12
Ceratophrydae:		
Ceratophrys ornato	Horned frog	2
Hylidae:		
Hyla sp	Tree frog	1
Hyla crucifer	Tree frog	2
Pipidae:		
Pipa pipa	Surinam toad	2
Xenopus laevis	African clawed frog	2
Ranidae:		
Rana clamitans	Green frog	2
Rana pipiens	Leopard frog	10
Rana sylvatica	Wood frog	1

FISHES

Anabas testudineus	Climbing perch	5
Anoptichthys jordani	Blind characin	12
Barbus everetti	Clown barb	17
Barbus partipentazona	Banded barb	8
Brachydanio albolineatus	Pearl danio	2
Brachydanio rerio	Zebra danio	3
Carassius auratus	Goldfish	2
Channa asiatica	Snakehead	1
Corydoras sp	South American catfish	3
Danio malabarica	Blue danio	2
Gymnocorymbus ternetzi	Black tetra	2
Hippocampus sp	Sea horse	2
Hyphessorbrycon innesi	Neon tetra	1
Kryptopterus bicirrhis	Glass catfish	1
Lebistes reticulatus	Guppy	100
Lepidosiren paradoxa	South American lung fish	2
Limia vittata	Cuban limia	10
Mesonauta insignis		11
Mollienisia sphenops	Victory molly	8
Monocirrhus polyacanthus	Leaf fish	2
Otocinclus affinus	Sucker catfish	6
Platypoecilus maculatus	Red moon	8
Poecelobucon unifasciatus	Pencil fish	1

Scientific name	*Common name*	*Number*
Pristella riddlei	Tetra	12
Protopterus annectens	African lungfish	2
	Black wagtail	1
ARACHNIDS		
Eurypelma sp	Tarantula	2
Latrodectus mactans	Black widow spider	1
INSECTS		
Blabera sp	Giant cockroach	100
MOLLUSKS		
Achatina achatina	Giant land snail	9
Achatina fulica	Zanzibar-Madagascar snail	3

Respectfully submitted.

W. M. MANN, *Director*.

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the operations of the Astrophysical Observatory for the fiscal year ended June 30, 1948:

The Observatory organization comprises the office of the Director (which includes three shops for the preparation of equipment: the wood, glass, and metal shops) and two research divisions: (1) the Division of Astrophysical Research and (2) the Division of Radiation and Organisms.

In September 1947 W. H. Hoover was promoted to be Chief of the Division of Astrophysical Research. Mr. Hoover has been a member of the Observatory staff since 1923. It is a sad duty to record the death on December 17, 1947, of Dr. Earl S. Johnston, Chief of the Division of Radiation and Organisms. Dr. Johnston joined the division at its beginning in 1929 and was responsible for a large portion of its development in recent years. Before the close of the fiscal year the Observatory was fortunate in completing arrangements to have Dr. Robert B. Withrow, of Purdue University, succeed Dr. Johnston as Chief of the Division, beginning September 1, 1948. During the year Dr. R. L. Weintraub, biochemist, and L. B. Clark, expert glass blower and technologist, transferred to National Defense agencies.

(1) DIVISION OF ASTROPHYSICAL RESEARCH

The year may be characterized as one of exploration and development since considerable effort was expended in search for a suitable high-altitude site for a third solar station, and in planning and preparing new equipment. It is proposed at the new station not only to conduct routine solar-constant observations, but also to test new electronic equipment and to conduct special researches. One project planned is a day-to-day study of changes in the infrared band of ozone at 9 microns wave length. For this work a special double spectroscope designed by Dr. Abbot, research associate, is being constructed by the Gaertner Scientific Corporation. New mirrors, aluminized and coated with magnesium fluoride, for both coelostat and spectrobolometer are on order. A fused-quartz prism, very free of bubbles, has been completed, also a new vacuum bolometer. The bolometer, planned and built by L. B. Clark, is so designed that the vacuum around the bolom-

eter strips will not deteriorate with time. Preliminary tests show it to be about three times as sensitive as the bolometers we are currently using.

Work at Washington.—The observations and computations from the Montezuma and Table Mountain field stations were carefully checked and appraised. Results for the calendar year 1947 were tabulated in the form given in table 24 of volume 6 of the Annals of the Astrophysical Observatory.

Arrangements were completed for the preparation of new and completely revised editions of the Smithsonian Meteorological Tables and the Smithsonian Physical Tables. Work on the Meteorological Tables is now in progress under the editorship of R. J. List, of the United States Weather Bureau. The Physical Tables will be edited beginning September 1, 1948, by Dr. William E. Forsythe, formerly of the Nela Research Laboratories, Cleveland, Ohio.

The sun and sky radiation studies at Camp Lee, Va., under contract with the Office of the Quartermaster General, were terminated on January 1, 1947, at the completion of 2 full years of observations. These observations included continuous records of the total sun and sky radiation, and of the relative energy in the ultraviolet, visible, and infrared portions of the spectrum, as received on a horizontal surface, on a plane 45° to the east, and on a plane 45° to the south. Part of the instrumental equipment was left at Camp Lee, and observations are being continued there under the sponsorship of the Camp Lee Quartermaster Board. A total of 16 reports were submitted to the Office of the Quartermaster General, summarizing the Smithsonian observations.

Under an extension of the contract with the Office of the Quartermaster General, equipment for radiation measurements similar to those made at Camp Lee was prepared for the temporary sea-level station (Miami, Fla.), and for the high-altitude, dry station at Montezuma, Chile. These preparations were under the direction of Mr. Hoover, chief of the division. One difficulty encountered in the Camp Lee work was the great amount of time required to read and sum up the many daily records, and special efforts were made to devise an automatic integrator. Mr. Hoover succeeded in working out the details of such a device, and three were built by the instrument maker, Mr. Talbert. The device is now in successful operation at the Miami station. It separately sums up the reading of four different recording pyrheliometers as registered on a four-point Brown electronic potentiometer. By simply taking the readings on each of four counters, the total radiation received by each of the four pyrheliometers is obtained. The results have repeatedly been checked against a complete reading of the record, and the integrator has proved surprisingly accurate.

Dr. Abbot, research associate of the Observatory, has made further contributions in his studies of relationships between solar changes and weather (see list of publications below). Mr. Hildt, mentioned in last year's report as assisting Dr. Arctowski in his researches concerned with the solar and terrestrial atmospheres, found it necessary to end this work on October 1, 1947. Miss Joyce Wilson substituted for Mr. Hildt for the remainder of the fiscal year.

Work in the field.—Regular observations for the determination of the solar constant were continued throughout the year at two high-altitude stations, Montezuma, Chile (9,000 ft.) and Table Mountain, Calif. (7,500 ft.). In addition, at Montezuma preparations were made for exposures of certain textiles and observations of the amount and quality of sun and sky light, similar to the work now in progress at the Miami station. However, unexpected delay was encountered in the transfer of part of the equipment to Montezuma, so that these exposures and observations had not yet been started at the close of the fiscal year.

As stated in last year's report, a cooperative program was arranged between the General Motors Corp., the Quartermaster Department, and the Smithsonian Institution for exposures and radiatiton measurements to be carried out at the General Motors Test Field at Miami, Fla. The program also included the mounting and servicing of the panels and filter boxes by the South Florida Test Service, under the direction of E. M. DeNoon. In November 1947, panel exposures both in the open and under filters, at an angle of 45° to the south, were begun at Miami. The measuring instruments and the filters are similar to those used at Camp Lee, Va. In addition, the spectrobolometer formerly at the Tyrone, N. Mex., station has been mounted and adjusted. Whenever the sky is sufficiently clear of clouds, bolographs are taken just as in our usual solar-constant program. From these bolographs we obtain valuable data concerning sea-level water-vapor conditions, as well as additional data on the relative distribution of energy throughout the spectrum as received from direct sunlight. The complete program was started in December 1947.

In July 1947 the Director began a tour in search of the most promising high-altitude site to which to transfer the Miami spectrobolometric equipment at the conclusion of our sea-level observations. It was thought that possibly somewhere in the high plateau region of Mexico sufficiently cloudless and pure skies might be found. With the cordial cooperation of the staff of the National Observatory of Mexico, at Tacubaya, many records of sky conditions were examined and several promising sites were visited. It is regretted that though the climate was uniformly delightful and invigorating, none of these sites proved to be sufficiently cloudless. Floating clouds are very prevalent.

In September, while vacationing in Honolulu, the Director learned of a site on the island of Hawaii where the annual rainfall is less than 10 inches and the skies described as remarkably clear. He visited that location where, at an altitude of 6,500 ft., he found a road, abundant water supply, electric power and telephone already installed, and skies which may prove to be clear and uniform from day to day.

In October Dr. Abbot and A. F. Moore visited the region of southern California near the Nevada border, including Clark Mountain (7,900 ft.), where the annual precipitation is 3 inches. They encountered excellent skies in this region.

Since tests covering an extended period are the only safe criteria for determining a satisfactory site for a solar station, Mr. Hoover in May 1948 installed a recording Eppley pyrheliometer at each of the three following promising sites: (1) Torreon, Coahuila, Mexico; (2) Mountain Pass, Calif., near Clark Mountain; and (3) Pohakuola, Island of Hawaii. The instruments are operated through the kind cooperation of men living near the sites. The records for the month of June 1948 indicate Clark Mountain as having the best skies thus far.

Dr. Abbot and the Director spent a month beginning August 10, 1947, at the Mount Wilson Observatory, Calif., having planned to assist each other on two projects. One project was to redetermine the Smithsonian standard scale of solar radiation. We reconditioned, remounted, and adjusted our standard double water-flow pyrheliometer, last used in 1934, and made a series of careful comparisons between it and two substandard silver-disk pyrheliometers which we had carried by hand from Washington. The mean of 33 comparisons agrees within 1 part in 1,000 with the results of 1934 and 1932. This confirms our belief that the scale of an individual silver-disk pyrheliometer with ordinary care will remain unchanged over a long period of years.

The second project was a continuation of Dr. Abbot's previous work to determine the energy spectra of some of the brighter stars, with the aid of the 100-inch Mount Wilson telescope. Dr. Abbot's sensitive radiometer, now under excellent control, permitted actual measurements on eight different stars at eight different wave lengths. Since the percentage accidental error was rather large, only the general forms of these curves were determined. Dr. Abbot has encouraging plans for improvement in the measurements and he hopes to repeat this project in the near future.

(2) DIVISION OF RADIATION AND ORGANISMS

Owing to the illness and death of the chief of the division, Dr. Earl S. Johnston, and to changes in personnel, the research program in progress at the beginning of the year was necessarily altered and somewhat curtailed. Leonard Price, now the senior staff member of

the division, has as far as possible arranged to bring current projects to satisfactory completion and to undertake no new projects except those of short duration.

Dr. Weintraub, after his transfer to a National Defense agency, continued periodic visits to the division to complete certain phases of his work. In these visits Mr. Price found his advice and aid of much value in rounding out the current experimental work. The following summarizes the work accomplished:

Several years ago, Dr. McAlister developed in the division an instrument for measuring accurately and quickly by spectroscopic means the carbon dioxide content of a volume of gas. Dr. Johnston later made certain modifications and carefully tested the instrument. Dr. Weintraub and Mr. Price subsequently used it in a study of the effect of plant growth regulators on the respiration of potato tubers. After the construction of a larger respiration chamber, a similar study was started using broad-leaf plants. This project was nearly completed at the close of the year.

Two new thermostats, installed early in the year, aided greatly in the control of environmental factors in germination studies using lettuce seeds. The effects of temperature, light, composition of atmosphere, and composition of substrate have been studied individually and in combination. Two phases of this study are completed and a third nearly completed.

Considerable progress was made in studies of the developmental physiology of grass seedlings. Growth curves for both mesocotyls and coleoptiles of plants grown under various combinations of controlled environmental conditions have been obtained. Plants grown in various salt solutions have yielded information on cation and anion effects. Salts show a retarding effect during initial germination which is then followed by a period of extended growth beyond that of plants grown in the absence of salts. The retardation and extended growth periods are proportional, within limits, to the concentration of the salt used. Several papers on these developmental physiology studies are in preparation.

The histological study of the mesocotyl, which was undertaken to explain the gross morphology effects of various environmental conditions, was continued for only part of the year. Being a long-range project, it was abandoned to permit the completion of other projects that were further advanced. However, before this work was stopped the cellular development of mesocotyls of etiolated corn seedlings had been charted.

A report is in preparation on the study of the effects of various fungicides on the germination and development of grass seedlings. Experimentation for this problem has been completed.

PUBLICATIONS

The following publications relating to the work of the Observatory were issued during the year:

Abbot, C. G. Precipitation affected by solar variation. Smithsonian Misc. Coll., vol. 107, No. 9, August 1947.

Abbot, C. G. A revised analysis of solar-constant values. Smithsonian Misc. Coll., vol. 107, No. 10, August 1947.

Abbot, C. G. 1947–1948 report on the 27.0074-day cycle in Washington precipitation. Smithsonian Misc. Coll., vol. 110, No. 4, March 1948.

Abbot, C. G., Solar variation attending West Indian hurricanes. Smithsonian Misc. Coll., vol. 110, No. 1, April 1948.

Abbot, C. G. Magnetic storms, solar radiation, and Washington temperature departures. Smithsonian Misc. Coll., vol. 110, No. 6, June 1948.

Abbot, C. G., and Aldrich, L. B. Energy spectra of some of the brighter stars. Smithsonian Misc. Coll., vol. 107, No. 19, February 1948.

Aldrich, L. B., and Abbot, C. G. Smithsonian pyrheliometry and the standard scale of solar radiation. Smithsonian Misc. Coll., vol. 110, No. 5, April 1948.

Aldrich, L. B., and associates: Reports to the Office of the Quartermaster General on Camp Lee studies. (Report No. 12 through No. 15, and special report of May 17, 1948.)

Weintraub, R. L. The influence of light on chemical inhibition of lettuce seed germination. Smithsonian Misc. Coll., vol. 107, No. 20, May 1948.

Weintraub, R. L., and Price, L. Inhibition of plant growth by emanations from oils, varnishes, and wood. Smithsonian Misc. Coll., vol. 107, No. 17, March 1948.

Weintraub, R. L., and Price, L. Influence of illumination on reducing sugar content of etiolated barley and oat seedlings. Smithsonian Misc. Coll., vol. 110, No. 2, March 1948.

Respectfully submitted.

L. B. Aldrich, *Director.*

Dr. A. Wetmore,
Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE NATIONAL AIR MUSEUM

SIR: I have the honor to submit the following report on the operations of the National Air Museum for the fiscal year ended June 30, 1948.

ESTABLISHMENT

Although the National Air Museum came into being as a new bureau of the Smithsonian Institution on August 12, 1946, through the enactment of Public Law 722, and an organizational and survey program was inaugurated shortly thereafter, actual operations of the bureau in its own right did not begin until August 1, 1947, one month after the beginning of the fiscal year. On that date the authorized appropriation of $50,000 for National Air Museum purposes became available to the Institution.

Thereupon, and in accordance with a previously prepared plan of operations, there was effected by administrative action the interbureau transfer of the Institution's aeronautical collection and the staff charged with its care, from the United States National Museum to the National Air Museum. As a matter of record the Smithsonian Institution has been gathering and safeguarding significant aeronautical materials for over 70 years. At the time of the transfer this nucleus for an air museum consisted of over 3,500 objects, comprising the most valuable collection of its kind in the United States, or, in fact, in the world. By this transfer the National Air Museum began its active life with full responsibility for the proper operation of a "going" aeronautical museum. Until it has a building of its own, the Air Museum has assigned for its use the metal hangar known as the Aircraft Building and, in addition, a certain amount of exhibition, office, and storage space in the Arts and Industries Building of the National Museum. The Air Museum will share, too, with its affiliates the various auxiliary services of the Smithsonian Institution.

On completion of the transfer of the aeronautical collections, administrative action was begun to provide the nucleus for an adequate staff for the new bureau. By March 1948 a force of seven persons (an addition of five to the original staff of two) was actively engaged in the many ramifications of the bureau's work.

Another matter given early attention in establishing the Air Museum was that of obtaining working quarters. These were provided in the West-South Range of the Arts and Industries Building of the National Museum and were available to the staff beginning June 15, 1948.

ADVISORY BOARD

Two meetings of the Air Museum's Advisory Board were held during the year, on August 19, 1947, and April 15, 1948, respectively. The problems of major concern to the Board this year were the acquisition of a storage depot for the temporary safekeeping of Air Museum material, and the determination of a suitable land site and building for the Air Museum. Both meetings of the Board centered largely on these two problems.

Prior to the August meeting a careful study had been made by the Air Museum's staff and by Mr. Loening, Board member, of several proposed storage depots. As a result a recommendation was made to the Board at the August meeting suggesting the selection of a part of the Douglas aircraft plant built during World War II and located on the outskirts of Park Ridge, Ill., about 20 miles northwest of Chicago. After due deliberation, including consideration of the fact that aeronautical museum material gathered by the United States Air Force for the National Air Museum was stored in this plant, the Board accepted the recommendation and by resolution directed that "the Chairman plan the operations of the National Air Museum in such a way that it will be prepared to take over and operate the storage facility at Park Ridge . . ."

In considering the problem of sites and a building for the Air Museum (the planning of which was authorized by law establishing the National Air Museum) the merits and advantages of various locations in the Nation were fully considered at the August 1947 Board meeting. The discussion led to the unanimous adoption of a resolution that "the National Air Museum should be located in Washington, and that search be made for sites which are to be submitted to the Advisory Board for approval as to location and adequacy in size."

Regarding an appropriate building for the Air Museum, the Board discussed at length the scope of the aeronautical collections to be assembled, the quantity of full-size historical and irreplaceable aircraft that merited consideration for a place in the future building, and the many factors involved in the maintenance, exhibition, and preservation of the collection. To further the study of the building problem the Board at its August 1947 meeting directed the Chairman to enlist the aid of the Public Buildings Administration of the Federal

Works Agency and to submit a report at the next Board meeting. Following a full and detailed discussion of this report, the Advisory Board approved the basic study and building plan presented and instructed the Chairman to proceed with the building study to determine costs.

PLANNING

STORAGE OF MUSEUM MATERIAL

Immediately following the selection by the Advisory Board of a portion of the Douglas plant near Park Ridge, Ill., for the storage of Air Museum material, negotiations were begun to obtain this facility. Following the termination of World War II this Douglas plant, which had been built during the war by the Government, was taken over by the U. S. Air Force and used in part as a storage facility and in part as headquarters of the Air Arm of the Illinois National Guard. Subsequently, control and management of the property was placed in the hands of the Air Defense Command of the United States Air Force, where it rested at the close of the year.

While negotiations for storage space in this building were under way, attention was given to plans for the Museum's operating organization at Park Ridge. The protection, preservation, and maintenance of the stored Air Museum material will constitute the principal responsibilities of this field organization. There is planned, therefore, for this field service a staff of 14, consisting of an associate curator with administrative and aircraft-maintenance experience, in charge, an aircraft technician, 10 guards, and 2 skilled laborer helpers.

MUSEUM SITE AND BUILDING

As indicated earlier in this report real progress was made during the year on the investigation of sites and a building for the Air Museum. The staff worked closely with the Office of Design and Construction of the Public Buildings Administration, contributing realistic concepts of a functional museum structure from knowledge gained through many years' experience in the engineering and industrial museum field. The staff furnished, too, much factual material representing considered judgment as to the essential requirements of the proposed building. In this connection the incorporation of a place of honor for the Wright Brothers' original aeroplane of 1903 was given full consideration. The advice and suggestions of Mr. Loening, Board member, regarding this important matter were most helpful.

The entire museum structure will require in excess of 500,000 square feet of exhibition area, providing for an expected initial collection of some 200 full-size aircraft, and for future expansion of the collection.

In addition there will be incorporated within the structure the usual space for offices, laboratories, library, auditorium, manufacturers' display rooms, and shops, as well as facilities for building maintenance and operation.

CURATORIAL ACTIVITIES

The curator, Paul E. Garber, reports on the year's work as follows:

EXHIBITION

The close of the fiscal year finds the exhibits in greatly improved condition. All full-size aircraft were given a thorough cleaning; several required minor repairs; four engines were reconditioned and remounted. The exhibition of many propellers was improved. The insignia which provide a colorful border to the walls of the Aircraft Building were touched up. A number of bases and cases were renovated and numerous scale models were repaired. At the suggestion of Gen. Frank Lahm and with the advice and assistance of Orville Wright, the lever which controls the balance and steering on the Wright Brothers' Military Flyer of 1909 was remodeled to conform with its condition when in active service. The incomplete parts of the John J. Montgomery gliders of 1905 and 1911 which had been accessioned the previous year were partly assembled. The series of frames containing the illustrated story of the Wright Brothers received additional drawings and photographs depicting more facts in this chronicle. Two large cased exhibits were formed to group engines of types used by the "Early Birds" (pioneer flyers of 1903–16) and those of World War I. The gondola of the balloon *Explorer–2*, which 13 years after its ascent still holds the world's absolute manned altitude record, had its rigging elevated to make a more understandable display. The exhibition of the Norden bombsight by which the atomic bomb was directed at Hiroshima was improved by adding two large photographs to illustrate its destructive effect. Extensive rearrangements of cases effected improvements in space and groupings, and a program of relabeling provided better captions for numerous items.

Several special exhibits were prepared: The first use of aircraft for polar exploration was undertaken by Salamon Andrée and two companions, 1897. Their heroic effort was commemorated by the Air Museum on the fiftieth anniversary of their departure. During the month of August the U. S. Air Force displayed current flight equipment including engines, ordnance, instruments, and training devices. The featured item was a Lockheed P–80 jet-powered fighter. The National Air Museum prepared a historic aeronautic display for Air

Force Day at Bolling Field, D. C. When the Navy's Douglas *Skystreak* established a new world speed record of 650.6 miles per hour on August 20–25, 1947, this event was soon featured in the Museum by a representative display which included a 1:16-size scale model of the *Skystreak*, a drawing showing its functional parts, autographed photographs of the pilots, and views of the plane in flight. May 15, 1948, marked the thirtieth anniversary of the establishment of air mail on a permanet scheduled basis. The Air Museum had an outstanding display ready for the anniversary. Special exhibits were also prepared by the staff on the occasions of meetings of the Smithsonian's Board of Regents and the Air Museum's Advisory Board.

INFORMATIONAL SERVICES

The Air Museum conducts public relations and educational services through correspondence, by telephone, and by personal contact, a function that requires more curatorial attention than any other phase of the Air Museum's work. The Department of Education of the State of California adopted the Handbook of the National Aircraft Collection as a reference book for use in schools and ordered a number of copies. The American Helicopter Society was given drawings and texts to illustrate early rotor experiments. The Air Transport Association was furnished details on the first commercial air load, and the curator served as judge for the annual Science Fair held in Washington, May 3, 1948. The Boeing Aircraft Co. and the Curtiss-Wright Corp. required photographs of pioneer types of their own historic craft. Technical charts prepared by the Douglas Aircraft Co., Inc., were checked and corrected for historic accuracy.

The regrettable death of Orville Wright and the expected return to America of the famous aeroplane invented and flown by him and his brother brought a flood of requests for information on Wright aircraft and details of the brothers' lives.

Acknowledgments.—Many sources were consulted by the staff in order to accomplish their duties. The curator wishes to acknowledge the valued help of Dr. W. R. B. Acker of the Freer Gallery in translating Japanese inscriptions on ex-enemy equipment and Dr. Waldo L. Schmitt of the National Museum in making German translations; the aid by Charles Burgess of the Department of the Navy in reviewing the development of lighter-than-air craft; the constant assistance of Alfred Verville, also of the Department of the Navy, in locating and evaluating naval objects of museum interest; and the supplying, by the Department of the Air Force, through Lt. Robert Strobell, of Wright Field, of extensive data on ex-enemy aircraft. The Naval Air Reserve Training Unit, Anacostia NAS, provided expert technical

help in conditioning and mounting several aircraft engines, and the engineering branch of the Bolling Field Air Force Base dismantled, moved, and assembled the Curtiss Racer R3C-2 for reexhibition in the Museum's aeronautical hall.

Lectures.—The curator gave the following lectures:

October 22, Optimists' Club of Arlington, Va.: National Air Museum's progress and plans.

January 21, a group of grade-school teachers at the Air Museum: Significance of the collections to school groups.

February 18, a group of 22 Turkish aviators: Tour of the collections.

March 20, a broadcast over station WGAY: The Air Museum's place in aeronautical education.

March 24, the Civil Aeronautics Club: The history of aeronautics.

March 31, the Civil Aeronautics Club: Tour of the collections.

May 21, Women Flyers' Club of Berkeley, Calif.: The National Air Museum's program.

May 30, Oakland Airport, Calif.: Plans for the National Air Museum.

June 6, Los Gatos, Calif., at the home of Robert Fowler (first to fly across the United States, eastward, 1911): Representations of "Early Birds" in the national collections.

June 11, Aviation Committee of the Bay Area, San Francisco: Representations of California airmen in the National Air Museum.

The associate curator gave one broadcast, as follows:

June 8, a broadcast over station WOL: The famous B-29 bomber *Enola Gay*.

SURVEY

In accord with the Advisory Board's motion, which inaugurated an extensive survey to locate desirable aeronautic materials, much curatorial time was devoted to: first, research to decide what items should be added to the collection; second, extensive correspondence to investigate availability, condition, and arrange procurement; third, meetings at the Air Museum with prospective donors; and fourth, visits to locate, examine, and receive material. The results of successful surveys are shown in the list of accessions.

Very helpful information on the condition of foreign aeronautical collections, and a number of leads for procurement of objects, resulted from a trip abroad by Mr. Loening, Board member, during August and September. The thorough manner in which he inspected museums, and the report, photographs, and catalogs which he brought back enabled the staff to gain a first-hand impression of the extent of air exhibits in England, France, and, to a certain extent, in Germany.

ACCESSIONS

The following listing of 45 accessions and 330 objects constitutes the largest lot of aeronautical acquisitions recorded in any year of the Smithsonian's history.

NATIONAL AIR MUSEUM ACCESSIONS DURING THE FISCAL YEAR ENDED JUNE 30, 1948

(Except where otherwise indicated, these have been entered as gifts or transfers)

AEROJET ENGINEERING CORP., Azusa, Calif.: (Through D. A. Kimball) 2 JATO rocket motors (178901).

AIR TRANSPORT ASSOCIATION OF AMERICA, Washington, D. C.: (Through Admiral Emory S. Land) 5 bound manuals relative to scheduled United States air lines' work in World War II (179056).

AVERY, JOHN B. (See under Consolidated Vultee Aircraft Corp.)

BAUSCH & LOMB CO., Rochester, N. Y.: (Through K. E. Reynolds) A current form of bubble sextant and accessories for celestial navigation (178841).

BELLINGER, Vice Admiral P. N. L., Washington, D. C.: A United States flag and a naval pennant flown on a Curtiss C–3 United States Navy flying boat during extended air scouting operations at Veracruz, Mexico, 1914 (179055).

BELT, Ambassador GUILLERMO. (See under Cuba, Republic of.)

BENDIX AVIATION CORP., South Bend, Ind.: (Through Cameron, Kerkam, and Sutton) A sectionalized Stromberg "injection carburetor" developed by the donors just before World War II and used on the majority of American military planes (179058).

BROOKS, EDITH, Washington, D. C.: Group of mementos from Air Meet at Nice, France, April 1910 (179060).

BROWN, Lt. K. S., Biloxi, Miss.: 50 specimens of German and Japanese aircraft instruments of World War II (179701), 5 items on loan.

CAMERON, KERKAM, AND SUTTON. (See under Bendix Aviation Corp.)

CARROLL SCHOOL OF AVIATION, Latrobe, Pa.: An Ackerman landing wheel, 1918 (176869).

CLINE, AL. (See under Northrop Aircraft, Inc.)

CONSOLIDATED VULTEE AIRCRAFT CORP., San Diego, Calif.: (Through John B. Avery) 3 models, 1:48 size, of World War II Consolidated-Vultee designed aircraft: PBY–5 Catalina Flying Boat, PB2Y–3 Coronado Flying Boat, and B–24 Liberator Bomber (178899).

CRUVER MANUFACTURING CO., Chicago, Ill.: (Through C. L. Cruver, Jr.) A set of 82 plastic scale model airplanes manufactured by the donor for the United States Navy and Army Air Corps during World War II (178941).

CUBA, REPUBLIC OF: (Through Guillermo Belt, Ambassador, Washington, D. C.) A diploma and medal in commemoration of the Pan American group flight of 1937, "pro Faro-Colon," granted by the Cuban Government (178900).

DATER, HENRY M. (See under National Military Establishment, *Department of the Navy.*)

DE HAVILLAND AIRCRAFT CO., LTD., Hatfield, Herfordshire, England: (Through Martin Sharp) A 1:16-size model of the De Havilland *Comet*, winner of the MacRobertson London to Melbourne Race, 1934 (179057).

DE YOUNG, M. H., MEMORIAL MUSEUM, San Francisco, Calif.: (Through Dr. Walter Heil) Nose fragment from the 1910 Antoinette airplane which was flown by Hubert Latham and made a number of West Coast flights (178955, loan).

DOUGLAS AIRCRAFT CO., INC., Santa Monica, Calif.: (Through G. B. Gelly) 2 scale model airplanes, 1:16 size, of Douglas types: the AD–1, carrier-based attack plane, and the D–558, *Skystreak* jet airplane which established the recent world's speed record (179700). Five charts illustrating characteristics of the earth's atmosphere and graphic presentations of transportation speeds (177266).

FIFE, Capt. WILLIAM P., Johnson City, Tenn.: A Japanese parachute, World War II, picked up by the donor in the Philippines at Clark Field, 1945 (178940).

FORD, HARRY H., Bridgeport, Conn.: A Roberts engine, an El Arco radiator and a wooden propeller used on donor's Curtiss type "hydroaeroplane," 1912–13, and a photograph which shows the plane with donor at controls, taking off from Bridgeport Harbor, Conn., July 4, 1912 (179698).

FORD, LYMAN. (See under Pioneer Parachute Co., Inc.)

GARBER, PAUL EDWARD, Washington, D. C.: An original Currier & Ives print illustrating the use of Thaddeus Lowe's Civil War Balloon at the Battle of Fair Oaks, Va., May 31, 1862 (176970).

GARDNER, GEORGE. (See under Pan American World Airways System.)

GELLY, G. B. (See under Douglas Aircraft Co., Inc.)

GOODRICH CO., B. F., Akron, Ohio: (Through H. W. Maxson) Stratosphere pressureized suit, designed and constructed by the donor organization for United States Air Forces (179106).

HEIL, DR. WALTER. (See under M. H. DeYoung Memorial Museum.)

HICKS, SGT. WILLIAM T., Washington, D. C.: Winter flying suit used by Japanese aviators in World War II (178840); a Japanese aerial bomb of the small antipersonnel type (179061).

HOVEY, Brig. Gen. B. M. (See under National Military Establishment, *Department of the Air Force.*)

JACOEL CABLE SPLICING EQUIPMENT CO., Philadelphia, Pa.: (Through J. Reaney) A Jacoel machine and kit used for splicing aircraft cables (175189).

KEIP, F. B., Santa Clara, Calif.: A group of 26 photographs illustrating the accomplishments of Prof. John J. Montgomery of Santa Clara University in his glider flights, 1905–11 (179258).

KIMBALL, D. A. (See under Aerojet Engineering Corp.)

KOPPERS CO., INC., Baltimore, Md.: (Through John D. Waugh) 2 examples of Aeromatic propeller development in the past 10 years and a 3-bladed German VDM propeller (179611).

KOVNAT, BERNARD. (See under United Air lines.)

LAND, Admiral EMORY S. (See under Air Transport Association of America.)

LASKOWITZ, I. B., Brooklyn, N. Y.: A wind-tunnel test model of a rotary unit as applied to a direct-lift rotary winged aircraft; and reference material (178990).

LOENDORF, WALTER, Waukesha, Wis.: A pair of goggles worn by Rear Admiral Albert C. Read (then Lt. Cmdr.) when commanding the Navy's NC–4 flying boat which accomplished the first trans-Atlantic flight, 1919 (179609).

MAXSON, H. W. (See under B. F. Goodrich Co.)

MCROBERTS, Sgt. ROBERT L., Washington, D. C.: 2 original photographs of Lilienthal gliders, 1896, obtained from Otto Lilienthal's son by the donor in Augsburg, Germany, 1945 (178938).

MUZZY, A. V., Tyler Tex.: Experimental ground-to-air human pick-up equipment invented by donor in 1937 (176281).

NATIONAL MILITARY ESTABLISHMENT:

Department of the Air Force, Washington, D. C.: (Through Brig. Gen. B. M. Hovey) 2 insignia painted on masonite plaques illustrating devices for identifying airplanes based at Bolling Field, D. C. (178716); (through Gen. Carl Spaatz) a German machine gun, World War I, recovered from one of the 54 planes shot down by the French ace, Georges Guynemer; originally presented in December 1946 to Gen. Carl Spaatz by Mr. Guynemer's sister Mme. de la Noue (178839, loan).

Department of the Navy, Bureau of Aeronautics, Washington, D. C.: (Through Capt. Leroy Simpler) Material illustrating the recent world speed record flight established by the U. S. Navy with the Douglas airplane *Skystreak* (179696); (through Rear Admiral A. M. Pride) Japanese Baka suicide rocket aircraft bomb of the type used against our naval forces in the later part of World War II (178989). From Naval Air Station, Patuxent River, Md.: (Through Capt. C. W. Seitz) A Kasei-22 14-cylinder twin-row air-cooled radial engine of the type used in the large Japanese Kawanishi 4-engine flying boat *Emily* (179610). From Office of the Chief of Naval Operations, Washington, D. C.: (Through Dr. Henry M. Dater) An original set of 82 pen-and-ink drawings made by artist Frank Tinsley for weekly syndication in newspaper feature sections, each depicting the exploits of a famous Marine air hero (179719).

NORTHROP AIRCRAFT, INC., Hawthorne, Calif.: (Through Al Cline) A 1:16-size scale model of the P–61C Black Widow night fighter, the XF–15 photo reconnaissance plane, and the N3PB twin-float patrol bomber (179059).

NORTHWEST AIRLINES, INC., St. Paul, Minn.: 1 set of double seats of the type used in their DC–4 airplanes (176933).

PAN AMERICAN WORLD AIRWAYS SYSTEM, New York, N. Y.: (Through Juan T. Trippe) 5 sets of double aircraft seats and 1 set of Pan American's DC–3 transport panel-chairs (178715, 179702). (These and other seats accessioned were donated for comfort and convenience of Museum visitors.) (Through George Gardner) 2 cutaway display models: a 1:10-size model of a Boeing 307 Strato-Clipper and a 1:16-size model of a Boeing 314 Flying Clipper (179417).

PIONEER PARACHUTE CO., INC., Manchester, Conn.: (Through Lyman H. Ford) Original parachute pack and harness (with a replacement canopy) used in making the first jump with a nylon parachute, June 6, 1942, and 4 framed photographs of Adeline Grey who made the jump (179697).

POWELL, LESTER W. B., Washington, D. C.: A 2-piece flying suit, used by the German Luftwaffe, World War II; it is stuffed with asbestos as a protection against flames (179257).

PRIDE, Rear Adm. A. M. (See under National Military Establishment, *Department of the Navy.*)

REANEY, J. (See under Jacoel Cable Splicing Equipment Co.)

REYNOLDS, K. E. (See under Bausch & Lomb Co.)

RICHARDSON, Brig. Gen. WILLIAM L., Washington, D. C.: A German machine gun mount taken from a JU–88 aircraft shot down in World War II (179699). (The donor affirms that the destruction of this aircraft was the final ground-to-air victory of the war.)

SEITZ, C. W. (See under National Military Establishment, *Department of the Navy.*)

SHARP, MARTIN. (See under DeHavilland Aircraft Co., Ltd.)

SIMPLER, Capt. LEROY. (See under National Military Establishment, *Department of the Navy.*)

SPAATZ, Gen. CARL. (See under National Military Establishment, *Department of the Air Force.*)

THOMAS A. EDISON, INC., West Orange, N. J.: (Through Arthur R. Tice) Group of 5 aircraft instruments (178939).

TICE, ARTHUR R. (See under Thomas A. Edison, Inc.)

TRIPPE, JUAN T. (See under Pan American World Airways System.)

UNITED AIR LINES, Chicago, Ill.: A 72-inch-span scale model of the Douglas DC-6 transport, and photos illustrating the transcontinental record set by this plane carrying passengers and crew, March 29, 1947, together with the National Aeronautical Association's homologation of that flight (179416); (through Bernard Kovnat) 2 sets of double aircraft seats from a DC-4 Mainliner 230 (179602).

WAUGH, JOHN D. (See under Koppers Co.)

Respectfully submitted.

CARL W. MITMAN,

Assistant to the Secretary for the National Air Museum.

DR. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE CANAL ZONE BIOLOGICAL AREA

SIR: It gives me pleasure to present herewith the annual report of the Canal Zone Biological Area for the fiscal year ended June 30, 1948.

TWENTY-FIFTH ANNIVERSARY

On April 17, 1948, the island laboratory celebrated its twenty-fifth anniversary. A special commemorative 10-cent stamp was issued by the Canal Zone, consisting of an outline drawing of the island, and within this the gato-solo (coati-mundi), the most versatile, intelligent mammal of the island. First-day covers, containing the 1947 annual report, were sent to those who had been on the island during the past 25 years, and many very interesting replies were received.

SCIENTISTS AND THEIR STUDIES

Dr. T. C. Schneirla, curator of the department of animal behavior of the American Museum of Natural History, continued his studies on army-ant behavior, assisted by Dr. Ernst Enzmann, of the Harvard Biological Laboratories, and by R. Z. Brown, of Swarthmore College. They "investigated the behavioral and biological conditions of two army-ant species, *Eciton hamatum*, a typical column raider, and *E. burchelli*, a typical swarm raider. The studies were begun in early November 1947 and continued through March 1948, thus starting late in the rainy season and extending well into the latter part of the dry season."

The study was concerned particularly with the manner in which army-ant colonies adapt to dry-season conditions, and the manner in which these ants produce their fertile females (dichthadiigynes). The project was designed to complete a general investigation on army-ant behavior and biological conditions begun in 1932 on Barro Colorado Island.

As a result of the findings, it is now clear that but one sexual brood per colony appears annually in the army ants, and that the pre-conditions of this brood are peculiar to the dry season. With further information about the timing of the one sexual brood per year and the conditions of its production, the implications of the army-ant situation for problems of caste and sex determination now are clearer.

The single sexual brood of 2,000 to 3,000 males and a dozen or less queen-type individuals is somehow produced by a functional queen which otherwise delivers huge all-worker broods at regular intervals throughout the year.

Facts concerning queen production in *Eciton* were checked in the study of a number of colonies. It was found that the number of young queens matured was very small, as a rule less than a dozen. They are fully developed in advance of the males, usually about 3 days. This female precocity proves to be very important for the process of colony division. Since young queens are present as adults before the males begin to emerge from their cases, it is possible for subsectioning of the colony to occur on a chemical-attraction basis before emergence of males arouses the colony into a move from its statary bivouacking site. The old colony queen is apt to be present in one of the subsections which becomes a new colony, one of the young new queens in another; these move off divergently and thenceforth behave as new colonies. The other young queens, through an interesting behavior process in the worker, are "sealed off" and eventually abandoned.

Dr. R. A. Johnson, State Teachers College, Oneonta, N. Y., came to the island when Dr. Schneirla and his associates were studying their army ants; hence it was a splendid opportunity for him to study the birds that attend the swarm raids of these ants, their various types of adjustment to habitat, territorialism, and social stimulation. In addition to the ant birds proper (Formicariidae), birds of other groups were found associated with these ant swarms. These associations differ distinctively, although all are represented by species of the Formicariidae.

Mrs. Dorothy Hobson, vice president of the Indiana Audubon Society, spent 2 months studying primarily the birds of the island, their nesting habits, and general behavior. She added much valuable information which will appear soon in published form.

Miss Clara Alma Moore, of Indianapolis, Ind., acompanied Mrs. Hobson and devoted most of her time to painting the birds in their natural habitats, nestings, and also some of the more conspicuous flowers. In addition she also made studies of nesting habits of birds.

Fred E. Moorehouse and Don F. Loughnan, of the Forest Products Laboratory of the United States Department of Agriculture at Madison, Wis., made careful inspection of the various types of container-grade plywood which have been in test on the island for several years. This also included cleated-plywood boxes. The tests were made to determine the effectiveness of various glues, glue preservatives, and toxic water-repellent treatments on the maintenance of quality of container-grade plywood when exposed to tropical conditions. The information obtained provides data desired by the Air Forces, as well

as adding much to the laboratory's knowledge of the effects of tropical exposure on these various types of plywoods. A comprehensive report on these results was prepared.

Dr. Edna Robbins, biology teacher at the Mary C. Wheeler School for Girls, Providence, R. I., spent a short time on the island to get acquainted with the tropical flora and certain of the invertebrates, and to add to her knowledge of environmental factors.

Dr. A. Brazier Howell, formerly of Johns Hopkins University, now retired, spent 10 days on the island in December, accompanied by Mrs. Howell, for the purpose of noting the changes that have taken place since he studied here 19 years ago. "A period of this duration can have practically no effect on a tropical rain forest undespoiled by man, and undoubtedly the habitat under which the fauna exists at this locality is now as nearly identical in comparison with two decades ago as it can be. But it is probable that the fauna is now in a more stable state than it was then. As time passes the absence of human interference, coupled with the segregation essential in an island habitat, results in an adjustment in the interrelationship of the elements of the fauna that is as near natural as can possibly be."

Dr. Marshall H. Stone, formerly of Harvard, and now with the Department of Mathematics of the University of Chicago, accompanied by Mrs. Stone, likewise spent a short time on the island, with broad interests in fauna and flora.

Dr. Nevin S. Scrimshaw, of the University of Rochester Medical School, returned to the island for a brief visit, to make a survey of the fresh-water fishes in connection with his previous studies there on this subject.

John Sellman, of the Sayville High School, New York, spent a short time on the island studying the animal life, in order to be able to give first-hand knowledge of the life in the American humid Tropics to his students. He has published several interesting articles on his observations.

H. C. Secrest, entomologist in the Division of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, came in order to make examinations of the several thousand soil-poison tests and treated-wood series installed by Kowal, Dews, and Johnson, and reported upon in the 1947 report. The results of these experiments are most interesting, but no conclusions are being announced as yet.

Fred W. Gottschalk and R. B. Putnam, of the American Lumber & Treating Co., of Chicago, Ill., came in order to get first-hand information on the very large series of termite tests being conducted by the Bureau of Entomology and Plant Quarantine. These tests, begun nearly a quarter of a century ago, are, in fact, a history of wood preservation.

Dr. Eugene Eisenmann, lawyer of New York City and an ornithologist of note, again spent some time on the island studying the birds and, as in the past, added many new records. The island is greatly indebted to him not only for sound advice, but also for his repeated assistance in other ways.

W. Doyle Reed, who is in charge of the entomological work for the United States Army, visited the Isthmus in connection with arrangements for the extension of this work in the army units here. Many conferences were held with the resident manager, and a short stay was made on the island to get acquainted with the entomological studies being conducted there. He was accompanied by Maj. Osborn A. Kinzer, C. E., of Dallas, Tex.; Maj. J. Phoble, C. E., of the Caribbean Defense Command; Maj. Ralph W. Bunn, M. Sc., of the Surgeon General's Office; Walter V. Kell, O. C. E., of Washington; and Col. Karl R. Lundberg, M. C., of the Office of the Chief Health Officer of the Panama Canal.

Jerry H. Staedeli, stationed with the army at Corozal, mainly interested in reptiles, spent 2 weeks on the island observing and recording the fauna seen, covering more than 30 miles of trails, as well as about 20 miles in a cayuco around the island.

Per Host, from Norway, ornithologist and mammalogist, spent considerable time on the island, chiefly in photographic work. Never before has the island had a visitor with the equipment he had for both still and motion pictures. He made over 3,000 feet of what are probably the finest motion pictures ever taken of the animals of the island, and many hundred "stills" in black and white and in color. He duplicated successfully a number of the experiments recorded by Chapman with the versatile coati-mundi, and has a splendid series of motion pictures of these in color. He also has slow-motion pictures of animals climbing and leaping. Most of his spectacular photography was taken from the main laboratory site. In his own words: "I am extremely satisfied both with the opportunities for getting pictures that I enjoyed, and for the education and introduction to the Tropics made possible by this unique combination of easy access to observations of a virgin jungle with the facilities of the laboratory and library."

Dr. C. C. Soper, in charge of the Tropical Research Laboratory of Eastman Kodak Co., continued his studies throughout the year on the effects of tropical conditions. Valuable data have been obtained on the keeping quality of film, papers, chemicals, and photographic equipment in general. Data have also been obtained on the tropical deterioration of photographic negatives and prints, particularly the deterioration attributable to biological origin. The studies on the island are also adding rapidly to the problems of tropical lighting conditions,

and the exposure of both black and white and color films, as well as to the related problem of film processing at high temperatures.

Many of the data have been utilized in the preparation of a manuscript on tropical photography, which when released will be of immediate help to photographers working in tropical and semitropical areas. This is a most valuable contribution and represents many years of careful, detailed study right in the Tropics, most of it on the island. The two basic sources of trouble are heat and humidity, especially the latter. In this work, Mr. Soper is assisted by Mr. Hermle.

James Zetek continued his studies on fruitflies, as well as the extensive termite tests in preparation for his forty-first progress report. This very large series of exposures, which in addition to termite tests, include rot, beetle, and other tests, is each year yielding more important data. In addition to this series, examinations were also made of the extensive soil-poison and treated-wood tests initiated and installed by Kowal-Dews-Johnson.

Smithsonian Institution. The following were visitors to the laboratory: Dr. Alexander Wetmore, Secretary, who had been in Herrera Province on ornithological reconnaissance, assisted by W. M. Perrygo, visited the island in February and in April largely on plans and discussions with the resident manager. John E. Graf, Assistant Secretary, spent some time on the island, likewise in discussions of plans, as well as to get acquainted with the island and the Tropics in general. This was his first visit to the Tropics, and it left him with lasting impressions and with the urge to return soon. Thomas F. Clark, administrative accountant, also spent some time on the island to become acquainted with the general set-up and to discuss property and fiscal matters with the resident manager. These three visitors and counselors were most welcome.

Dr. Matthew W. Stirling, Director of the Bureau of American Ethnology, with Mrs. Stirling, and Richard Stewart, staff photographer for the National Geographic Society, recently returned from archeological explorations in the region of Parita, were welcome visitors in April.

STUDIES ON DETERIORATION AND CORROSION

During World War II a great amount of work was done on the island with refernce to deterioration and corrosion, much of it related to war needs. As the program continued, it became more and more apparent that the island was especially well fitted for this sort of work, and that in addition, the isolation gave security. The studies included not only fabrics, foodstuffs, and corrosion of lenses, but also packing and packaging, the use of substitute materials, and similar

problems. High temperatures and humidities, especially the latter, with the growth of fungus and other organisms, create serious problems. Elsewhere in this report reference is made to the large number of such studies undertaken by Eastman Kodak Co., as a result of which it is possible to avoid many of these difficulties. It is believed that this phase of practical studies should be expanded, and facilities will be granted to concerns and government units that have need for such information.

BUILDINGS

The main laboratory building, 32 by 55 feet, contains laboratories, a dining room, dormitory, and photographic darkroom. It is in excellent condition, showing neither termite damage nor rot. Three buildings—the Barbour guest house, the Chapman house, and the "Zetek" Z-M-A house—each provide adequate lodging for four persons, and the first two have ample laboratories. The kitchen building has on the second floor a dormitory for six persons. Other buildings are the masonite building used by the labor force; the caretaker's home; the library; Zetek's quarters, a concrete-block building used as office and living quarters for the resident manager; and the kodak test building, which is itself a termite test in addition to housing Eastman Kodak's exposure tests for corrosion and deterioration.

The remaining buildings are five small structures, each located at the end of one of the island trails. All are available for the use of scientists, each structure accommodating two persons. These buildings are also practical termite tests.

A paper entitled "Inspection of Test Buildings Treated for Termites on Barro Colorado Island, Canal Zone, Panama," by Thomas E. Snyder and James Zetek, was published in the March 1948 issue of Pests and Their Control, Kansas City. Those interested in the effectiveness of treated wood in termite control will find this report of value.

IMPROVEMENTS MADE

Both the coal-tar creosoted and cypress water tanks were in such bad condition that replacements were necessary, and a concrete tank of 4,000 gallons was built at a cost of about $400. This tank is for safe drinking water. Since plans had to be made for a much more adequate gravity-flow water supply, a site was selected for a new 14,000-gallon concrete water tank on the Snyder-Molino trail. The area has been cleared and leveled, and the necessary galvanized pipe procured. Work on the tank will be started when the rains subside.

The present dock, owing to the silting of the bay and the low level

of Gatun Lake, had to be enlarged. The new center dock, which has concrete piers, should be adequate for many years to come. The old shingle roof of the Fuertes House, at end of the Pearson trail, was replaced with one of galvanized corrugated iron.

TABLE 1.—*Annual rainfall, Barro Colorado Island, Canal Zone*

Year:	*Total inches*	*Station average*	Year:	*Total inches*	*Station average*
1925	104.37	------	1937	124.13	110.12
1926	118.22	113.56	1938	117.09	110.62
1927	116.36	114.68	1939	115.47	110.94
1928	101.52	111.35	1940	86.51	109.43
1929	87.84	106.56	1941	91.82	108.41
1930	76.57	101.51	1942	111.10	108.55
1931	123.30	104.69	1943	120.29	109.20
1932	113.52	105.76	1944	111.96	109.30
1933	101.73	105.32	1945	120.42	109.84
1934	122.42	107.04	1946	87.38	108.81
1935	143.42	110.35	1947	77.92	107.49
1936	93.88	108.98			

TABLE 2.—*Comparison of 1946 and 1947 rainfall, Barro Colorado Island, Canal Zone (inches)*

Month	Total		Station average	Years of record	Excess or deficiency	Accumulated excess or deficiency
	1946	1947				
January	0.45	0.40	1.84	22	−1.44	−1.44
February	0.32	2.14	1.27	22	+0.87	−0.57
March	1.71	0.54	1.42	22	−0.88	−1.45
April	1.41	3.09	2.81	23	+0.28	−1.17
May	8.05	4.82	10.85	23	−6.03	−7.20
June	7.94	12.06	11.31	23	+0.75	−6.45
July	12.58	7.53	11.63	23	−4.10	−10.55
August	10.50	11.76	12.53	23	−0.77	−11.32
September	10.67	9.53	10.43	23	−0.90	−12.22
October	9.00	13.17	13.17	23	----------	−12.22
November	14.98	7.25	18.78	23	−11.53	−23.75
December	9.77	5.63	11.45	23	−5.82	−29.57
Year	87.38	77.92	107.49	----------	----------	−29.57
Dry	3.89	6.17	7.34	----------	----------	−1.17
Wet	83.49	71.75	100.15	----------	----------	−28.40

URGENT NEEDS

First on the list of urgent needs is a more adequate supply of electricity on a 24-hour daily basis. The present small generators are inadequate, and the equipment is in need of repair. An addition is needed for the kitchen to make room for electric refrigerators. To reduce fire risk, the present kitchen and the proposed addition should be remade of concrete blocks and tile. Also on the urgent list is a larger building of concrete blocks to take care of the expanding library and herbarium, as well as the species index and scientific equipment, all of which must be in a fireproof building with provision for heaters to reduce the humidity.

A new concrete water tank of 14,000-gallons capacity mentioned above will be built this coming fiscal year. It will be located on the Snyder-Molino trail, high enough so that there will be good gravity flow with a strong enough head to it. The tank will be so built that the height can be increased later on to provide for more storage.

The Chapman and the Barbour houses should be rebuilt with concrete blocks and tile, and increased in size.

FISCAL REPORT

During the fiscal year 1948, $12,934.25 in trust funds was available. Of this amount $11,478.64 was spent, leaving on hand only $1,455.61 with which to face the new fiscal year. In addition to this amount, $1,458.20 is still on deposit, representing local collections, and there will be added a few table subscriptions, but, even with these, the coming year will be a rather difficult one financially.

During this fiscal year only $1,907.75 was collected as fees from scientists, as compared with $4,403.96 last year. This decline is largely due to the high cost of ocean or air travel, and efforts should be made to obtain concessions which will reduce materially this heavy expense. The laboratory, despite the higher costs of food and other items, has not increased its per diem charge to scientists.

The institutions listed below continued to aid materially in the support of the laboratory through payment of table subscriptions. These institutions, because of their support, are given a 25 percent reduction in the per diem for such scientists as come to the laboratory.

Smithsonian Institution	$300
American Museum of Natural History	300
Eastman Kodak Company	1,000
New York Zoological Society	300
University of Chicago	300

It is most gratifying to record that the Smithsonian Institution increased its subscription by an additional $500.00 The Forest Products Laboratory of the United States Department of Agriculture contributed $550.00 as service fees for facilities furnished by the laboratory in connection with the termite and other tests on the island.

It is likewise most gratifying to record donations from Dr. Eugene Eisenmann of New York City, an ornithologist of note, from Mrs. G. S. Patton, Jr., and from Mrs. Laurie Randall.

The sum of $5,000 was made available by the Smithsonian Institution from appropriated funds, and of this amount $4,999.21 was used for permanent improvements.

Respectfully submitted.

JAMES ZETEK, *Resident Manager.*

DR. ALEXANDER WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 11

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1948:

The library received 53,129 publications during the year, 9,250 of which were transmitted by the International Exchange Service. They covered broadly the fields of astrophysics, botany, zoology, geology, anthropology, engineering, the fine and useful arts, history, and many related subjects. They came from all over the world, by purchase, by gift, and in exchange, and were written in many different languages.

Friends of the Institution continued to make generous gifts of books, pamphlets, and periodicals. Especially noteworthy among the 9,798 of the publications so received was the library of the late Charles B. Chaney, of Laurel, Md., a very fine collection of 1,510 books and periodicals on the history of railroads, presented for the special use of the division of engineering. The American Association for the Advancement of Science and the American Association of Museums continued to make large donations of current books and periodicals. The library is, as always, greatly indebted to these friends everywhere throughout the world for their contributions.

Purchased publications included 1,485 volumes and pamphlets, and 271 periodical subscriptions.

The library is primarily a working reference collection, not a museum of rare or fine books, but the interests and responsibilities of the Smithsonian Institution touch so wide and timeless a range of subjects that many old as well as new books are in daily use. A few of the out-of-print works purchased to fill lacunae in various subject fields were the following: A Natural History of Singing Birds, by Eleazar Albin, Edinburgh, 1776; History of Early Steamboat Navigation on the Missouri River, by H. M. Chittenden, New York, 1902, 2 volumes; Art Sales from early in the Eighteenth Century to early in the Twentieth Century, by Algernon Graves, London, 1918–21, 3 volumes; Atlas der Baumgarten von Java, by S. H. Koorders, Leiden, 1913–18, 4 volumes; Voyages made in the Years 1788 and 1789, from China to the N. W. Coast of America, by John Meares, London, 1791, 2 volumes; Conchology, or Natural History of Shells, by E. Mendes da Costa, London, 1770–72, numbers 1–6; Monograph of the Snakes in Japan, by Moichiro Maki, with 85 colored plates and 158 text

figures, Tokyo, 1931, 2 volumes; The Printer's Grammar, by Charles Stower, London, 1808; Ceramic Literature: an Analytical Index to the Works Published in All Languages on the History and Technology of the Ceramic Art, by L. M. E. Solon, London, 1910; The Voyage of the *Challenger*, a Personal Narrative of the Historic Circumnavigation of the Globe in the Years 1872–1876, by Herbert Swire, London, 1938, 2 volumes; Der Französische Kupferstich der Renaissance, by Erika Tietze-Conrat, Munich, 1925; Zeitschrift für die Entomologie, edited by E. Germar, Leipzig, 1839–44, 5 volumes.

Serial publications, which include not only regularly issued periodicals, but the reports, bulletins, proceedings, monographs, and other publications of learned societies and research institutions, of museums and art galleries, of universities, libraries, and laboratories everywhere, form the largest and probably the most indispensable part of the library's holdings. Except for the periodical parts represented by the 271 purchased subscriptions and a few received as gifts, all those added to the library during the year came in exchange for the Institution's own publications. Currently entered were 15,256 periodical parts, and many annual volumes and irregularly issued serials were cataloged. Many gaps in serial sets, some of them of long standing, were filled by the 6,782 volumes and parts received in response to 719 special requests. New exchanges arranged were 314.

To the great Smithsonian Deposit in the Library of Congress, first established in 1866, were sent 5,809 volumes and parts, many of them in continuation of files of the scientific and technical proceedings of learned societies. Also sent to the Library of Congress were 12,342 miscellaneous publications, including 1,023 dissertations on a great variety of subjects from 14 foreign and 3 American universities, and a large number of other books and periodicals on subjects not pertinent to the work of the Institution.

Most of the 2,339 publications transferred to government libraries other than the Library of Congress had been received during the year. Among them were 508 medical dissertations transferred to the Army Medical Library.

The cataloging of 6,148 volumes and pamphlets was completed during the year, and 35,357 cards were added to catalogs and shelflists. Except for a small number of older publications in urgent need of cataloging attention, the huge "backlog" of cataloging remained virtually untouched and must continue to remain so until an adequate staff for doing the work can be provided.

Funds were not sufficient to permit all the volumes of periodicals completed during the year to be sent to the bindery, but the diligent studies made by the Government Printing Office to reduce binding costs permitted 1,052 volumes or 436 more than last year to be bound

for approximately the same sum customarily allotted for binding. Because of illness on the staff the volumes repaired in the Museum, 826, were somewhat fewer than last year.

Although there was no member of the staff who could be detailed to work regularly with the library's large collection of duplicates, time was found to select 36,701 pieces for use in aid of destroyed libraries overseas.

The 10,151 publications borrowed for use outside the library can only hint at the actual use made of the library, which is the true test of its value to the Institution. Certainly many times that number of books and periodicals were consulted in the main reading rooms, the stacks, and the divisional libraries kept immediately adjacent to the offices and laboratories of the scientific staff in all the buildings of the Institution. The library staff itself answered more than 15,000 reference questions, most of which required the consultation of more than one, and some of them of many different publications.

The housing of the library continues to be its most serious unsolved problem. In an institution charged with responsibility for administering research in so many different highly specialized and technical fields, a good many relatively small decentralized collections of books and periodicals on special subjects are both necessary and desirable, but such decentralization should always be made in the direct interest of furthering the work of a given bureau or division, never merely as a housing convenience, or at the expense of lowering the working reference efficiency of the central library collections and consequently at the expense of the work of the institution as a whole. Our shelves are now so badly overcrowded everywhere that it has become impossible to avoid committing almost every sin in the library calendar, both of giving good care to the books and of giving good library service.

SUMMARIZED STATISTICS

Accessions

	Volumes	Total recorded volumes June 30, 1948
Astrophysical Observatory (including Radiation and Organisms)	344	12,587
Bureau of American Ethnology	145	34,607
National Collection of Fine Arts	470	11,444
National Museum	2,724	241,891
National Zoological Park	14	4,180
Smithsonian Deposit at the Library of Congress	1,800	578,673
Smithsonian Office	422	32,607
Total	5,919	915,987

Neither incomplete volumes of periodicals nor separates and reprints from periodicals are included in these figures.

Exchanges

New exchanges arranged	314
93 of these were assigned to the Smithsonian Deposit in the Library of Congress.	
Specially requested publications received	6,782
1,022 of these were obtained to fill gaps in the Smithsonian Deposit sets.	

Cataloging

Volumes and pamphlets cataloged	6,148
Cards added to catalogs and shelflists	35,357

Periodicals

Periodical parts entered	15,256
Of these 4,813 were sent to the Smithsonian Deposit at the Library of Congress.	

Circulation

Loans of books and periodicals	10,151
This figure does not include the intramural circulation of books and periodicals filed in 31 sectional libraries, of which no count is kept.	

Binding

Volumes sent to the bindery	1,052
Volumes repaired in the Museum	826

Respectfully submitted.

LEILA F. CLARK, *Librarian.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 12

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ended June 30, 1948.

The Institution published during the year 22 papers, 1 title page and table of contents, and 1 reprint of a paper in the Smithsonian Miscellaneous Collections, 1 Annual Report of the Board of Regents and pamphlet copies of 17 articles in the Report appendix, 1 Annual Report of the Secretary, and 2 special publications.

The United States National Museum issued 1 Annual Report, 17 Proceedings papers, 4 Bulletins, and 2 separate papers in the Bulletin series, Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued 1 Annual Report and 2 volumes of Bulletin 143.

The Institute of Social Anthropology issued 4 publications.

Of the publications there were distributed 165,740 copies, which included 15 volumes and separates of Smithsonian Contributions to Knowledge, 44,338 volumes and separates of Smithsonian Miscellaneous Collections, 25,242 volumes and separates of Smithsonian Annual Reports, 6,922 War Background Studies, 12,215 Smithsonian special publications, 65 reports on the Harriman Alaska Expedition, 50,970 volumes and separates of National Museum publications, 14,203 publications of the Bureau of American Ethnology, 10,834 publications of the Institute of Social Anthropology, 17 catalogs of the National Collection of Fine Arts, 66 volumes and pamphlets of the Freer Gallery of Art, 15 Annals of the Astrophysical Observatory, 760 reports of the American Historical Association, and 78 miscellaneous publications not printed by the Smithsonian Institution (mostly Survival Manuals).

SMITHSONIAN MISCELLANEOUS COLLECTIONS

In this series there were issued title page and table of contents of volume 91, 14 papers in volume 107, whole volumes 108 and 109, 6 papers in volume 110, and a reprint of 1 paper in volume 74, as follows:

VOLUME 91

Title page and table of contents. (Publ. 3903.) Aug. 29, 1947.

VOLUME 107

No. 7. The insect cranium and the "epicranial suture," by R. E. Snodgrass. 52 pp., 15 figs. (Publ. 3896.) July 30, 1947.

No. 8. Some implications of the ceramic complex of La Venta, by Philip Drucker. 9 pp., 6 pls. (Publ. 3897.) July 30, 1947.

No. 9. Precipitation affected by solar variation, by C. G. Abbot. 4 pp., 2 figs. (Publ. 3901.) Aug. 11, 1947.

No. 10. A revised analysis of solar-constant values, by C. G. Abbot. 9 pp., 2 figs. (Publ. 3902.) Aug. 30, 1947.

No. 11. Notes on the neotropical Dictyopharidae and synonymy in two other groups, by R. G. Fennah. 13 pp., 2 pls. (Publ. 3904.) Nov. 24, 1947.

No. 12. The Wineland voyages, by John R. Swanton. 81 pp. (Publ. 3906.) Dec. 15, 1947.

No. 13. The Edmonton, Kentucky, meteorite, by E. P. Henderson and S. H. Perry. 4 pp., 4 pls. (Publ. 3907.) Oct. 31, 1947.

No. 14. A review of the races of the spotted babbling thrush, *Pellorneum ruficeps* Swainson. 20 pp. (Publ. 3908.) Oct. 20, 1947.

No. 15. Report on collections of birds made by United States Naval Medical Research Unit No. 2 in the Pacific war area, by Lt. Rollin H. Baker. 74 pp., 6 pls., 9 figs. (Publ. 3909.) Mar. 22, 1948.

No. 16. Charles T. Simpson's types in the molluscan genus *Liguus*, by Frederick M. Bayer. 8 pp., 1 color pl. (Publ. 3910.) Apr. 3, 1948.

No. 17. Inhibition of plant growth by emanations from oils, varnishes, and woods, by Robert L. Weintraub and Leonard Price. 13 pp., 8 pls. (Publ. 3912.) Mar. 10, 1948.

No. 18. A review of the American menhaden, genus *Brevoortia*, with a description of a new species, by Samuel F. Hildebrand. 39 pp., 9 figs. (Publ. 3913.) Mar. 22, 1948.

No. 19. Energy spectra of some of the brighter stars, by C. G. Abbot and L. B. Aldrich. 9 pp., 1 pl., 3 figs. (Publ. 3914.) Feb. 27, 1948.

No. 20. Influence of light on chemical inhibition of lettuce seed germination, by Robert L. Weintraub. 8 pp. (Publ. 3915.) May 27, 1948.

VOLUME 108

Compendio y descripcion de las Indias Occidentales, por Antonio Vázquez de Espinosa, transcribed by Charles Upson Clark. 801 pp. (Publ. 3898.) [May 10], 1948.

VOLUME 109

Smithsonian elliptic functions tables, by G. W. and R. M. Spenceley. iv+366 pp. (Publ. 3863.) Nov. 1, 1947.

VOLUME 110

No. 1. Solar variation attending West Indian hurricanes, by C. G. Abbot. 7 pp., 1 fig. (Publ. 3916.) Apr. 20, 1948.

No. 2. Influence of illumination on reducing sugar content of etiolated barley and oat seedlings, by Robert L. Weintraub and Leonard Price. 3 pp. (Publ. 3917.) Mar. 10, 1948.

No. 3. The amphipods of the Smithsonian-Roebling Expedition to Cuba in 1937, by Clarence R. Shoemaker. 15 pp., 3 figs. (Publ. 3918.) Apr. 20, 1948.

No. 4. 1947–1948 report on the 27.0074-day cycle in Washington precipitation, by C. G. Abbot. 2 pp. (Publ. 3919.) Mar. 10, 1948.

No. 5. Smithsonian pyrheliometry and the standard scale of solar radiation, by L. B. Aldrich and C. G. Abbot. 4 pp. (Publ. 3920.) Apr. 15, 1948.

No. 6. Magnetic storms, solar radiation, and Washington temperature departures, by C. G. Abbot. 12 pp., 2 pls., 4 figs. (Publ. 3940.) June 25, 1948.

REPRINT: VOLUME 74

No. 1. Smithsonian mathematical formulae and tables of elliptic functions, by Edwin P. Adams and Col. R. L. Hippisley. Second reprint. 314 pp. (Publ. 2672.) Jan. 15, 1948.

SMITHSONIAN ANNUAL REPORT

Report for 1946.—The complete volume of the Annual Report of the Board of Regents for 1946 was received from the Public Printer October 13, 1947:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1946. ix+440 pp., 53 pls., 24 figs. (Publ. 3871.)

The general appendix contained the following papers (Publs. 3872–3888):

On the astronomical dating of the earth's crust, by Harlow Shapley.
Atomic power in the laboratory and in the stars, by Robert S. Richardson.
Atomic energy as a human asset, by Arthur H. Compton.
The scientific importance of X-rays, by L. Henry Garland.
Visible patterns of sound, by Ralph K. Potter.
Fluorine in United States water supplies—Pilot project for the Atlas of Diseases, by Anastasia Van Burkalow.
The birth of Parícutin, by Jenaro Gonzalez R. and William F. Foshag.
The natural history of whalebone whales, by N. A. Mackintosh.
Life history of the quetzal, by Alexander F. Skutch.
The sun and the harvest of the sea, by Waldo L. Schmitt.
Anthropology and the melting pot, by T. D. Stewart.
Archeology of the Philippine Islands, by Olov R. T. Janse.
Palestinian pottery in Bible times by J. L. Kelso and J. Palin Thorley.
The march of medicine, by M. M. Wintrobe.
Technology and medicine, by Kurt S. Lion.
National responsibility for research, by J. E. Graf.
Toward a new generation of scientists, by L. A. Hawkins.

Report for 1947.—The Report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the Annual Report of the Board of Regents to Congress, was issued January 9, 1948:

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1947. ix+169 pp., 4 pls. (Publ. 3911.) 1948.

The Report volume for 1947, containing the general appendix, was in press at the close of the year.

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SPECIAL PUBLICATIONS

The National Aircraft Collection, by Paul Edward Garber. Seventh edition. 43 pp., illus. (Publ. 3900.) [July 24], 1947.

Brief Guide to the Smithsonian Institution. Seventh edition. 80 pp., illus. [Apr. 9], 1948.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 1 Annual Report, 17 Proceedings papers, 4 Bulletins, and 2 separate papers in the Bulletin series, Contributions from the United States National Herbarium.

REPORT

Report on the progress and condition of the United States National Museum for the fiscal year ended June 30, 1947. iii+108 pp. Jan. 17, 1948.

PROCEEDINGS: VOLUME 96

No. 3206. A generic revision of the ichneumon-flies of the tribe Ophionini, by R. A. Cushman. Pp. 417–482, pls. 49–56. July 17, 1947.

No. 3207. Review of the weevils of the tribe Ophryastini of America north of Mexico, by Alonzo G. Davis. Pp. 483–551, figs. 49–77. July 8, 1947.

Title page, table of contents, list of illustrations, and index. Pp. i–vii, 553–572. Mar. 18, 1948.

VOLUME 97

No. 3208. Mammals of northern Colombia. Preliminary report No. 1: Squirrels (Sciuridae), by Philip Hershkovitz. Pp. 1–46, fig. 1. Aug. 25, 1947.

No. 3210. Studies on the firefly. IV: Ten new lampyrids from Jamaica, by John B. Buck. Pp. 59–79, pls. 1–3. Aug. 14, 1947.

No. 3211. A new genus and species of deep-sea fish of the family Myctophidae from the Philippine Islands, by Robert R. Miller. Pp. 81–90, fig. 2. July 18, 1947.

No. 3212. A review of the larvaevorid flies of the tribe Leskiini with the setulose first vein (R_1), by Maurice T. James. Pp. 91–115, fig. 3. Aug. 29, 1947.

No. 3213. The staphylinid beetles of the Cayman Islands, by Richard E. Blackwelder. Pp. 117–123. Oct. 31, 1947.

No. 3214. Mammals of northern Colombia. Preliminary report No. 2: Spiny rats (Echimyidae), with supplemental notes on related forms, by Philip Hershkovitz. Pp. 125–140. Jan. 6, 1948.

No. 3215. A synopsis of the larvaevorid flies of the genus *Eudejeania*, by Curtis W. Sabrosky. Pp. 141–156. Nov. 20, 1947.

No. 3216. The Pycnogonida of the western North Atlantic and the Caribbean, by Joel W. Hedgpeth. Pp. 157–342, figs. 4–53, 3 charts. Mar. 8, 1948.

No. 3217. Notes on some assassin bugs of the genus *Zelurus* from the collections of the United States National Museum, by Herman Lent and Petr Wygodzinsky. Pp. 343–349, pls. 4–7. Dec. 4, 1947.

No. 3218. New genera and species of echiuroid and sipunculoid worms, by Walter Kenrick Fisher. Pp. 351–372, pls. 8–15, fig. 54. Dec. 19, 1947.

No. 3219. Birds collected by the National Geographic Society's expeditions to northern Brazil and southern Venezuela, by Herbert Friedmann. Pp. 373–570, pls. 16–27. Apr. 9, 1948.

VOLUME 98

No. 3220. A revision of six subfamilies of atherine fishes, with descriptions of new genera and species, by Leonard P. Schultz. Pp. 1–48, pls. 1 and 2, figs. 1–9. Mar. 24, 1948.

No. 3221. Mammals of northern Colombia. Preliminary report No. 3: Water rats (genus *Nectomys*), with supplemental notes on related forms, by Philip Hershkovitz. Pp. 49–56. June 30, 1948.

No. 3223. Status of the pyraustid moths of the genus *Leucinodes* in the New World, with descriptions of new genera and species, by Hahn W. Capps. Pp. 69–83, pls. 5–10. June 24, 1948.

BULLETINS

No. 82. A monograph of the existing crinoids. Vol. 1, The Comatulids. Pt. 4b—Superfamily Mariametrida (concluded—the family Colobometridae) and superfamily Tropiometrida (except the families Thalassometridae and Charitometridae), by Austin Hobart Clark. Pp. i–vii, 1–473, 43 pls. Oct. 9, 1947.

No. 185, part 5. Checklist of the coleopterous insects of Mexico, Central America, the West Indies, and South America, by Richard E. Blackwelder. Pp. i–iv, 765–925. Oct. 31, 1947.

No. 193. A list and index of the publications of the United States National Museum (1875–1946). Pp. i–iv, 1–306. Dec. 19, 1947.

No. 194. An annotated checklist and key to the Amphibia of Mexico, by Hobart M. Smith and Edward H. Taylor. Pp. i–iv, 1–118. June 17, 1948.

CONTRIBUTIONS FROM THE UNITED STATES NATIONAL HERBARIUM

VOLUME 29

Part 4. The awnless annual species of *Muhlenbergia*, by Jason R. Swallen. Pp. i–ii, 203–208. Nov. 24, 1947.

VOLUME 30

Part 2. Observations on the grass flora of certain Pacific Islands, by L. T. Burcham. Pp. i–vii, 405–447, 4 figs., 7 pls. Mar. 10, 1948.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau continued under the immediate direction of the editor, M. Helen Palmer. During the year the following publications were issued:

REPORT

Sixty-fourth Annual Report of the Bureau of American Ethnology, 1946–1947. 30 pp.

BULLETINS

143. Handbook of South American Indians. Julian H. Steward, editor:
  - Vol. 3, The Tropical Forest tribes. 986 pp., 126 pls., 134 figs., 8 maps. June 3, 1948.
  - Vol. 4, The Circum-Caribbean tribes. 609 pp., 98 pls., 79 figs., 11 maps. June 30, 1948.

PUBLICATIONS OF THE INSTITUTE OF SOCIAL ANTHROPOLOGY

No. 4. Cultural and historical geography of Southwest Guatemala, by Felix Webster McBryde. 184 pp., 48 pls., 2 figs., 25 maps.

No. 5. Highland communities of Central Peru: A regional survey, by Harry Tschopik, Jr. 56 pp., 16 pls., 2 maps.

No. 6. Empire's children: The people of Tzintzuntzan, by George M. Foster. 297 pp., 16 pls., 36 figs., 2 maps.

No. 7. Cultural geography of the modern Tarascan area, by Robert C. West. 77 pp., 14 pls., 6 figs., 21 maps.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association. The following report volume was issued this year:

Annual Report of the American Historical Association for the year 1946. Volume 1, Proceedings.

The following were in press at the close of the fiscal year: Annual Report of the American Historical Association for 1943, vol. 2, Writings on American History. Annual Report of the American Historical Association for 1945, vol. 2, Spain in the Mississippi Valley, 1765–1794, Pt. 1, The Revolutionary period, 1765–1781; vol. 3, Spain in the Mississippi Valley, 1765–1794, Pt. 2, Postwar decade, 1782–1791; vol. 4, Spain in the Mississippi Valley, 1765–1794, Pt. 3, Problems of frontier defense, 1792–1794. Annual Report of the American Historical Association for 1947, vol. 1, Proceedings.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Fiftieth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, November 18, 1947.

APPROPRIATION FOR PRINTING AND BINDING

The congressional appropriation for printing and binding for the past year was entirely obligated at the close of the year. The appropri-

ation for the coming fiscal year ending June 30, 1949, totals $103,000, allotted as follows:

General administration (Annual Report of the Board of Regents; Annual Report of the Secretary)	$18,500
National Museum	41,000
Bureau of American Ethnology	15,500
National Air Museum	3,000
Service division (Annual Report of the American Historical Association; blank forms; binding)	25,000
	103,000

Respectfully submitted.

W. P. TRUE, *Chief, Editorial Division.*

DR. A. WETMORE,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1948

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s 6d— $508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

Since the original bequest, the Institution has received gifts from various sources, the income from which may be used for the general work of the Institution. These, including the original bequest, plus savings, are listed below, together with the income for the present year.

ENDOWMENT FUNDS

(Income for unrestricted use of the Institution)

Partly deposited in United States Treasury at 6 percent and partly invested in stocks, bonds, etc.

	Investment	Income present year
Parent fund (original Smithson bequest, plus accumulated savings)	$728,879.14	$43,710.60
Subsequent bequests, gifts, etc., partly deposited in the U. S. Treasury and partly invested in the consolidated fund:		
Avery, Robert S., and Lydia, bequest fund	54,093.08	2,529.83
Endowment fund	333,257.58	13,490.84
Habel, Dr. S., bequest fund	500.00	30.00
Hachenberg, George P. and Caroline, bequest fund	4,082.23	172.02
Hamilton, James, bequest fund	2,909.75	167.23
Henry, Caroline, bequest fund	1,227.61	51.73
Hodgkins, Thomas G. (general) gift	146,433.84	8,242.69
Porter, Henry Kirke, memorial fund	290,698.96	12,252.25
Rhees, William Jones, bequest fund	1,070.20	55.62
Sanford, George H., memorial fund	2,003.59	104.04
Witherspoon, Thomas A., memorial fund	130,990.25	5,520.92
Special fund, stock in reorganized closed banks	2,280.00	132.00
Total	969,547.09	42,749.17
Grand total	1,698,426.23	86,459.77

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These, plus accretions to date, are listed below, together with income for the present year.

	Investment	Income present year
Abbott, William L., fund, for investigations in biology	$103, 103. 28	$4, 393. 18
Arthur, James, fund, for investigations and study of the sun and lecture on same	40, 594. 59	1, 710. 95
Bacon, Virginia Purdy, fund, for traveling scholarship to investigate fauna of countries other than the United States	50, 854. 02	2, 143. 37
Baird, Lucy H., fund for creating a memorial to Secretary Baird	24, 438. 78	1, 030. 00
Barstow, Frederick D., fund, for purchase of animals for Zoological Park	1, 014. 79	42. 73
Canfield Collection fund, for increase and care of the Canfield collection of minerals	38, 822. 08	1, 636. 24
Casey, Thomas L., fund, for maintenance of the Casey collection, and promotion of researches relating to Coleoptera	9, 310. 03	392. 36
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	28, 583. 86	1, 204. 78
Eickemeyer, Florence Brevoort, fund, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr	514. 93	21. 66
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6, 671. 02	281. 13
Hitchcock, Dr. Albert S., library fund, for care of Hitchcock Agrostological Library	1, 601. 64	76. 27
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100, 000. 00	6, 000. 00
Hrdlička, Aleš and Marie, fund, to further researches in physical anthropology and publication in connection therewith	18, 667. 46	786. 79
Hrdlička, special	12, 500. 00	
Hughes, Bruce, fund, to found Hughes alcove	19, 429. 08	818. 88
Long, Annette and Edith C., fund, for upkeep and preservation of Long collection of embroideries, laces, etc	551. 16	23. 22
Maxwell, Mary E., fund, for care, etc., of Maxwell Collection	10, 006. 87	421. 74
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use and benefit of the National Collection of Fine Arts	19, 240. 71	810. 94
Strong, Julia D., bequest fund, for benefit of the National Collection of Fine Arts	10, 148. 79	427. 74
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	7, 523. 90	317. 11
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to $250,000	114, 499. 01	5, 152. 24
Rathbun, Richard, memorial fund, for use of division of U. S. National Museum containing Crustacea	10, 795. 86	454. 98
Reid, Addison T., fund, for founding chair in biology, in memory of Asher Tunis	30, 271. 31	1, 507. 57
Roebling Collection fund, for care, improvement, and increase of Roebling collection of minerals	122, 502. 71	5, 163. 18
Rollins, Miriam and William, fund, for investigations in physics and chemistry	95, 312. 29	4, 016. 45
Smithsonian employees' retirement fund	34, 382. 42	2, 903. 94
Springer, Frank, fund, for care, etc., of Springer collection and library	18, 202. 45	767. 14
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	381, 810. 92	16, 248. 55
Younger, Helen Walcott, fund, held in trust	50, 126. 48	3, 298. 96
Zerbee, Frances Brincklé, fund, for endowment of aquaria	962. 80	40. 78
Total	[1] 1,362, 443. 24	62, 092. 85

[1] Decrease indicated from total listed for last year is due to adjustments in value of certain real estate holdings and to the use of a part of the Smithsonian retirement fund to purchase pension rights due employees in their transfer to the Federal retirement system.

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his

will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42, as an endowment fund for the operation of the Gallery.

The above fund of Mr. Freer was almost entirely represented by 20,465 shares of stock in Parke, Davis & Co. As this stock advanced in value, much of it was sold and the proceeds reinvested so that the fund now amounts to $6,100,164.31 in a selected list of securities classified later.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes	$1,698,426.23
Invested endowment for specific purposes other than Freer Endowment	1,362,443.24
Total invested endowment other than Freer endowment	3,060,869.47
Freer invested endowment for specific purposes	6,100,164.31
Total invested endowment for all purposes	[1] 9,161,033.78

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the U. S. Revised Statutes, sec. 5591		$1,000,000.00
Investments other than Freer endowment (cost or market value at date acquired):		
Bonds	$670,887.62	
Stocks	1,258,220.55	
Real estate and first-mortgage notes	79,220.93	
Uninvested capital	52,540.37	
		2,060,869.47
Total investments other than Freer endowment		3,060,869.47
Investment of Freer endowment (cost or market value at date acquired):		
Bonds	$2,861,230.60	
Stocks	3,123,939.71	
Uninvested capital	114,994.00	
		6,100,164.31
Total investments		9,161,033.78

[1] Decrease indicated from total listed for last year is due to adjustments in value of certain real estate holdings and to the use of a part of the Smithsonian retirement fund to purchase pension rights due employees in their transfer to the Federal retirement system.

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1948[1]

Cash balance on hand June 30, 1947		$904, 356. 19
Receipts other than Freer endowment:		
Income from investments	$154, 933. 36	
Gifts and contributions	116, 450. 13	
Sales of publications	34, 407. 00	
Miscellaneous	24, 377. 26	
Sale and redemption of securities (net)	60, 104. 70	
Total receipts other than Freer endowment		390, 272. 45
Receipts from Freer endowment:		
Income from investments	$262, 328. 65	
Sale and redemption of securities (net)	69, 627. 73	
Total receipts from Freer endowment		331, 956. 38
Total		1, 626, 585. 02
Disbursements other than Freer endowment:		
Administrative	$47, 553. 24	
Publications	49, 395. 85	
Library	3, 596. 99	
Buildings—care, repairs, alteration	2, 282. 76	
Custodian fees, etc	3, 079. 70	
Miscellaneous	1, 093. 37	
Researches	130, 491. 98	
Smithsonian Retirement System	65, 665. 52	
Total disbursements other than Freer disbursements		303, 159. 41
Disbursements from Freer Endowment:		
Salaries	$75, 745. 70	
Purchases for collections	149, 800. 00	
Custodian fees, etc	11, 157. 07	
Miscellaneous	22, 638. 23	
Total disbursements from Freer endowment		259, 341. 00
Investment of current funds in U. S. Bonds		500, 237. 24
Total disbursements		1, 062, 737. 65
Cash balance June 30, 1948		563, 847. 37
Total		1, 626, 585. 02

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

ASSETS

Cash:			
United States Treasury current account	$418,087.11		
In banks and on hand	145,760.26		
	563,847.37		
Less uninvested endowment funds	166,613.23		
		$397,234.14	
Travel and other advances		7,438.61	
Cash invested (U. S. Treasury note)		500,237.24	
			$904,909.99
Investments—at book value:			
Endowment funds:			
Freer Gallery of Art:			
Stocks and bonds	$5,986,091.45		
Uninvested capital	114,072.86		
		6,100,164.31	
Smithsonian Institution:			
Stocks and bonds	1,929,108.17		
Real estate and mortgage notes	79,220.93		
Uninvested capital	52,540.37		
Special deposit in U. S. Treasury. Interest at 6 percent	1,000,000.00		
		3,060,869.47	
			9,161,033.78
			10,065,943.77

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:			
Income from Freer Gallery of Art endowment			$357,129.31
Income from other endowments:			
Restricted		$171,210.97	
General		87,474.88	
			258,685.85
Gifts and grants			289,094.83
			904,909.99
Endowment funds:			
Freer Gallery of Art		$6,100,164.31	
Other:			
Restricted	$1,362,443.24		
General	1,698,426.23		
		3,060,869.47	
			9,161,033.78
			10,065,943.77

The practice of maintaining savings accounts in several of the Washington banks and trust companies has been continued during the past year, and interest on these deposits amounted to $600.42.

In many instances, deposits are made in banks for convenience in collection of checks, etc., and later such funds are withdrawn and deposited in the United States Treasury.

Disbursement of funds is made by check signed by the Secretary of the Institution and drawn on the United States Treasury.

The foregoing report relates only to the private funds of the Institution.

The Institution gratefully acknowledges gifts from the following:

William G. Fargo.
John A. Roebling, as a further contribution for researches in radiation.
The Viking Fund, Inc., for Iroquois research.
American Philosophical Society, for Iroquois research.
E. R. Fenimore Johnson, for research in under-water photography.
National Geographic Society, expedition to Arnhem Land.
National Geographic Society, expedition to western Panama.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1948:

Salaries and expenses	$1,800,312.00
National Zoological Park	455,400.00

In addition, funds were transferred from other Departments of the Government for expenditure under direction of the Smithsonian Institution:

Cooperation with the American Republics (transfer from the State Department)	$94,882.00
Working Fund, transferred from the National Park Service, Interior Department, for archeological investigations in River Basins throughout the United States	73,800.00
Working Fund, transferred from Navy Department for research studies of radiation upon marine life as a result of atomic bomb tests at Bikini Atoll	11,000.00

The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

The report of the audit of the Smithsonian private funds follows.

SEPTEMBER 14, 1948.

TO THE BOARD OF REGENTS,
SMITHSONIAN INSTITUTION,
Washington 25, D. C.

We have examined the accounts of the Smithsonian Institution relative to its private endowment funds and gifts (but excluding the National Gallery of Art and other departments, bureaus, or operations administered by the Institution under Federal appropriations) for the year ended June 30, 1948, have reviewed the system of internal control and the accounting procedures of the Institution and, without making a detailed audit of the transactions, have examined or tested accounting records of the Institution and other supporting evidence, by methods and to the extent we deemed appropriate. Our examination was made in accordance with generally accepted auditing standards and included all procedures which we considered necessary in the circumstances.

The Institution maintains its accounts on a cash basis and does not accrue income and expenses. Land, buildings, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution.

In our opinion, the accompanying financial statements present fairly the position of the private funds and the cash and investments thereof of the Smithsonian Institution at June 30, 1948 (excluding the National Gallery of Art and other departments, bureaus or operations administered by the Institution under Federal appropriations) and the cash receipts and disbursements for the year.

PEAT, MARWICK, MITCHELL & CO.

Respectfully submitted.

ROBERT V. FLEMING,
VANNEVAR BUSH,
CLARENCE CANNON,
Executive Committee.

September 14, 19[illegible]

To the Board of Regents,
Smithsonian Institution,
Washington 25, D.C.

We have examined the accounts of the private endowment funds and gifts (but excluding the National Gallery of Art and other departments, bureaus, or operations administered by the Institution under Federal appropriations) for the year ended June 30, 19[illegible], have reviewed the system of internal control and the accounting procedures of the Institution and, without making a detailed audit of the transactions, have examined or tested accounting records of the Institution and other supporting evidence, by methods and to the extent we deemed appropriate. Our examination was made in accordance with generally accepted auditing standards and included all procedures which we considered necessary in the circumstances.

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Peat, Marwick, Mitchell & Co.

Respectfully submitted.

Robert V. Fleming,
Caryl Parker Haskins,
Clarence Cannon,
Executive Committee.

General Appendix

TO THE SMITHSONIAN REPORT

FOR 1948

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1948.

The Astrophysical Observatory of the Smithsonian Institution [1]

By C. C. Abbot, *Research Associate, Smithsonian Institution*

[With 6 plates]

The Astrophysical Observatory of the Smithsonian Institution is the child of S. P. Langley, third Secretary of the Institution. Owing to his very keen interest in the sun's radiation, he had invented the bolometer [2] about 1878, and about 1890 equipped it with photographic registration. His studies of the solar and lunar energy spectra were made not only at the Allegheny Observatory, but also at the summit of Mount Whitney, Calif., where he conducted an expedition to measure the amount of solar radiation.

As Langley had been so exclusively occupied with the distribution of energy in spectra, it is a little strange that in the first years of the Astrophysical Observatory at Washington, 1890–1900, he turned aside to the relatively less interesting subject of mapping the positions of lines in the infrared spectrum of the sun. Yet that was the Observatory program when I joined its staff in June 1895.

In order to observe infrared radiation not transmitted by glass, we were using large rock-salt prisms made from clear blocks of salt obtained from the Russian Government. Two noble rock-salt prisms were in our equipment, each about 7 inches tall and about 5 inches on edge. With these, after improving the bolometer so that drift and wiggle in the photographic trace of its galvanometer were greatly reduced, F. E. Fowle and I mapped the solar spectrum to wave length 5.3 microns, 53,000 angstroms, observing indications of more than 600 spectral lines and bands of solar or terrestrial origin. It was necessary to determine more exactly the dispersion of rock salt in order to fix the wave lengths. Our photographic registration, with the highly accurate mechanism furnished by Warner and Swasey, enabled us to give the values of the index of refraction of rock salt to six places of decimals. Because European observers scoffed at such pretensions, and cut our values down to four places, it was a comfort to us when Paschen repeated the determination and, finding only small differences from us in the sixth place, referred to our work as "of wonderful precision."

At the request of H. D. Babcock, and with the aid of Hugh Freeman, I repeated the bolometric mapping of the infrared solar spectrum in 1928 on Mount Wilson. With higher dispersion, improved apparatus, and long bolometric experience, we were able to detect evidences of over 1,200 lines and bands, some of solar, others of terrestrial origin, between wave lengths 0.76 and 2.0 microns. It was a great satisfaction, when I discussed this work with Babcock in 1945, to learn that he finds it still useful, and that there is almost nothing in our curves that is not confirmed by present photographic spectra or by theoretical physics.

[1] Reprinted by permission from Leaflet No. 216, Astronomical Society of the Pacific, with revision and the addition of illustrations by the author.

[2] The bolometer is an exceedingly sensitive instrument for measuring radiation by recording changes in its electrical resistance, produced by heating.

817369—49——12

The Solar Constant of Radiation, Its Imperfect Constancy, and Its Relationship to Meteorology

The main research of the Astrophysical Observatory from 1902 to the present time concerns what was beautifully and emphatically expressed by Langley in his report of the Mount Whitney expedition [3] as follows:

> If the observation of the heat the sun sends the earth is among the most important and difficult in astronomical physics, it may also be termed the fundamental problem of meteorology, nearly all whose phenomena would become predictable if we knew both the original quantity and kind of this heat; how much of it reaches the soil; how, through the aid of the atmosphere, it maintains the surface temperature of the planet; and how, in diminished quantity and altered kind, it is finally returned to outer space.

In the same report, Langley also said: "The difficulty of measuring sun rays accurately at the ground is indeed very great, but the difficulty of measuring their loss in the atmosphere is almost insuperable."

It was a great satisfaction, in view of these true statements of Langley, based on his long experience, when Turner, of Oxford, in a review of volume 2 of the Annals of the Astrophysical Observatory, wrote in 1908: "Mr. Abbot has shown that he is measuring something definite, for he has detected an annual diminution of 3½ percent from August to October, due to our greater distance from the sun."

Since then great improvements in accuracy, both in ground measures and in estimates of atmospheric losses, have been made. In a recent paper [4] I was able to show that a periodic change in the sun's output of radiation, averaging but 0.13 percent, can be recognized in our measurements of the last 25 years, and the form of its curve of solar variation can be clearly shown, though its whole average range is only one twenty-seventh of that which Turner referred to in 1908. The steps taken which have led up to the present condition of our research will now be mentioned.

After an interlude of observing the total solar eclipses of May 28, 1900, and May 18, 1901, we returned to Langley's first interest, measurements of the intensity in different parts of the solar spectrum, as observed on the earth's surface at low and high elevations above sea level, and as it would be observed at mean solar distance outside the atmosphere altogether. When we began these new studies, the 1900 edition of Hann's Lehrbuch of meteorology gave without preference values of the solar constant [5] of radiation, ranging from Pouillet's 1.76 calories per square centimeter per minute to Ångström's suggestion of 4.0 calories. Various types of instruments for measuring the total intensity of solar heating were then in use which disagreed widely. Only one of them, the Ångström electrical compensation pyrheliometer,[6] has survived to the present time, and that has been decidedly improved. But even as of the year 1900, Ångström's pyrheliometer was within 3 percent of the truth.

However, being unfamiliar with the merit of Angström's pyrheliometer, we developed our instrument from Pouillet's. After several years of improvements, we perfected the Abbot silver-disk pyrheliometer about 1910. Nearly a hundred copies of this in-

[3] Langley, S. P., A report of the Mount Whitney expedition. Prof. Pap. Signal Service, No. 15, p. 11, 1884.

[4] The sun's short regular variation and its large effect on terrestrial temperatures. Smithsonian Misc. Coll., vol. 107, No. 4, Apr. 4, 1947.

[5] The "solar constant" is the number of calories of radiant energy from the sun falling each minute on 1 square centimeter of surface at the earth's mean distance from the sun.

[6] The pyrheliometer is an instrument for measuring fairly intense beams of radiation. It is better adapted to absolute measures than the bolometer.

strument have been made by our instrument maker, Andrew Kramer, which are in use in all parts of the world. An Argentinian observer, Enrique Chaudet, has confirmed our own experience with them, for he finds them highly stable in sensitiveness over a period of 30 years, and capable of reading to an accuracy of one-fourth of 1 percent. We also devised the water-flow and the water-stir standard pyrheliometers. The

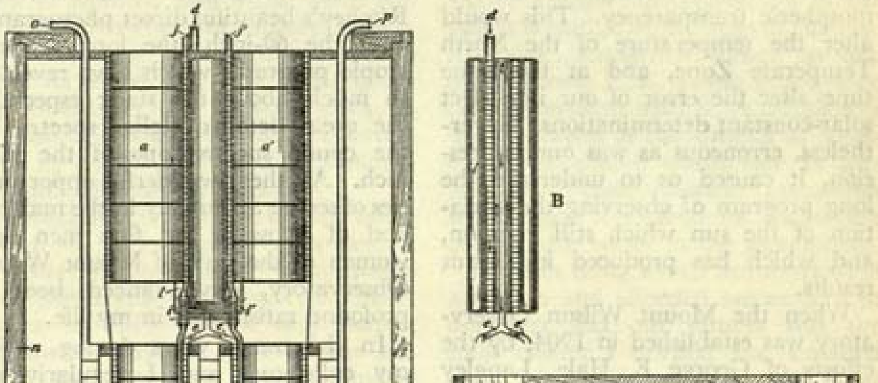


FIGURE 1.—Compensation water-flow pyrheliometer for standardizing instruments for measuring the intensity of the sun's radiation.

former we improved, as proposed by a Russian physicist, V. M. Shulgin, by employing two electrically compensated hollow chambers. With this improved instrument, L. B. Aldrich and I, in 1932, determined very accurately the absolute scale of the silver-disk instruments, used so generally the world over, and often referred to as "the Smithsonian scale of 1913."

Our first inkling that the sun's output of radiation, on which the earth's temperature depends, might be variable and thereby modify weather, came to us in 1903. Although the atmosphere over Washington, even 45 years ago, was very unsuitable for attempting solar-constant measurements, we had been making them occasionally in 1902 and 1903 on cloudless days. Suddenly, in March 1903, our results fell about 10 percent although carried on with the same instruments and methods as before. I made a statistical study of the temperatures of all available parts of the Northern Hemisphere and found the exciting result that simultaneously with the slump in solar-constant results there was a general fall of temperature from the normal over the whole North Temperate Zone. This work we showed to Secretary Langley and he published a paper on it.[7]

[7] On a possible variation of the solar radiation and its probable effect on terrestrial temperatures. Astrophys. Journ., vol. 19, No. 5, pp. 305, 307, 315–138, 321, June 1904.

With present knowledge we feel sure that the supposed change of 10 percent in the solar constant in March 1903 was illusory. At that time we had not perfected our methods to avoid errors in estimating the atmospheric losses. About that time, as in the eruption of Mount Katmai, Alaska, in 1912, there were several violent volcanic eruptions, including Colima, Mexico, and Pelee, West Indies. These, as in 1912, probably caused a great change in the atmospheric transparency. This would alter the temperature of the North Temperate Zone, and at the same time alter the error of our imperfect solar-constant determinations. Nevertheless, erroneous as was our impression, it caused us to undertake the long program of observing the variation of the sun which still goes on, and which has produced important results.

When the Mount Wilson Observatory was established in 1904, by the efforts of George E. Hale, Langley was invited to use that station for determinations of the solar constant of radiation and the range of variation of the sun's output of radiation. In 1905 I went to Mount Wilson with a large outfit, and was joined by L. R. Ingersoll, now head of the department of physics, University of Wisconsin. From 1905 to 1922, with few exceptions, my colleagues and I spent several months each year in solar-constant measurements on Mount Wilson. In more recent years I have occasionally revisited Mount Wilson for special observations.

Thus I have been priviledged to watch, as with a bird's-eye view, those great advances in astronomy which have justly given Mount Wilson Observatory a shining place in the world. I like to recall from time to time some of them. Hale's discovery of magnetism in sunspots; Adams' and St. John's spectroscopic measures of rotation of the sun; St. John's exact spectrum places; Adams' and Kohlschutter's spectroscopic parallaxes; Nicholson's and Pettit's measures of stellar and planetary radiation; Hubble's and Humason's work on the distant nebulae; Seares' photometric studies; and many more fine pieces of work that it is invidious not to mention. I saw the mountain transformed by George Jones' years of effort; the building of the road; the erection of the two solar tower telescopes and of the 60-inch and the 100-inch reflectors. I saw G. W. Ritchey's beautiful direct photographs with the 60-inch; the long spectroscopic programs which have revealed so much about the stars; especially the great detailed stellar spectra by the coudé spectroscope of the 100-inch. All these wonderful opportunities of seeing astronomy in the making, and of knowing the fine men and women of the staff of Mount Wilson Observatory, have indeed been a profound satisfaction in my life.

In the many years during which my colleagues and I regularly returned to Mount Wilson, we made many observations, in addition to those of the solar constant. As our measurements seemed to indicate a variability in the sun's output of radiation, we sought to check this important possibility in several ways. We erected a tower telescope on our observatory, and every day, after observing for the solar constant, we drifted an 8-inch image of the sun over the spectrobolometer, selecting a number of different wave lengths These drifts gave U-shaped curve. for the sun is less bright near the limbs than at the center. The contrast is much greater for violet than for infrared rays. It was our object to detect whether variations of the solar constant were associated with variations of the contrast of brightness between the edge and center of the sun. Some indications of such a correlation were indeed found. Another test of our supposed solar variation we made by expeditions to the summit

BRIGHTNESS DISTRIBUTION ALONG SUN'S DIAMETER FOR DIFFERENT COLORS

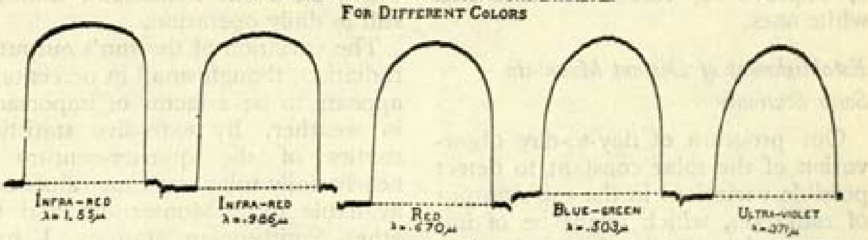


FIGURE 2.

of Mount Whitney in 1909 and 1910, and to Bassour, Algeria, in 1911 and 1912. Solar-constant measurements were made at these stations on the same days that they were being made on Mount Wilson. In later years, as I shall tell, we have amplified such tests by occupying mountain summits in other parts of the world.

Criticism of our solar-constant work, based on the supposed impossibility of correctly estimating atmospheric transparency, led us to special observations in 1913. On a very perfect September day we observed the sun with pyrheliometer and bolometer from the instant it rose until midday. From these observations, extending from air mass 20 to air mass 1.2, we computed a series of solar-constant values, instead of the usual one depending only on air mass change from 4 to 1.2. They agreed excellently. Also, at A. K. Ångström's suggestion, I designed an automatic recording pyrheliometer, to be carried by sounding balloons very high in the atmosphere. This was flown by L. B. Aldrich, in cooperation with the U. S. Weather Bureau, from Omaha, Nebr., and recovered in Iowa. It gave excellent records at 15 miles elevation, where the air pressure was only one twenty-fifth as great as at sea level. These records gave a value of solar radiation about 1 percent lower than those derived from solar-constant observing at Mount Wilson.

Both on Mount Wilson and on Mount Whitney I made many measurements of the intensity of sky light at all parts of the sky, both by day and by night. We also confirmed Lord Rayleigh's theoretical and observational studies of the blue of the sky. Applying Rayleigh's theory to our observations, F. E. Fowle found very close agreement with R. A. Millikan's determination of the number of molecules per square centimeter in air. He also made classical researches which gave a method for measuring precipitable water in the atmosphere.

Another thing which attracted wide attention and afforded amusement to ourselves and our visitors was the solar cooker I devised and installed close beside our cottage on Mount Wilson. It has a concave cylindric mirror which follows the sun by rotating about a pipe at the focus of the mirror, mounted parallel to the earth's axis. Cylinder oil in the pipe when heated by solar radiation circulates about ovens in a reservoir some 10 feet above the mirror. Mrs. Abbot used to cook food for ourselves and our visitors there for many years. She baked bread, cooked meat and vegetables, made jam, and, in short, did all kinds of cooking by solar heat except frying and roasting. The ovens remained hot enough to bake with, by night as well as by day, for months each year.

Several times in later years I attempted to measure the distribution of radiation in the spectra of the brighter stars, using a spectroscope at the coudé focus of the 100-inch reflector and a radiometer as my measuring instrument. I made interesting spectral-energy curves for yellow and red stars, but hope still

to improve my results for blue and white ones.

Establishment of Distant Mountain Solar Stations

Our program of day-to-day observation of the solar constant to detect possible variations in the sun's output of radiation, which might be of importance for weather forecasting, received a great impetus in 1916. H. H. Clayton, then chief forecaster of Argentina, sent us a paper[8] in which he showed that if our Mount Wilson solar-constant values were used in large groups, graded with respect to size, temperatures in all parts of the world seemed to be correlated with them. I reported on this paper to Dr. Walcott, then Secretary of the Smithsonian Institution, and he was also impressed.

Excellent as Mount Wilson atmospheric conditions are for photographic stellar work, the variable haziness, associated with nearby cities and the ocean, make it difficult to determine there the variations of the solar constant of radiation. After much inquiry it appeared that the region of Calama in northern Chile might prove more suitable. Dr. Walcott authorized an expedition to Calama, and in 1918 the Smithsonian established a solar observing station there, directed by Alfred F. Moore. In 1920, by the generous assistance of John A. Roebling, the Chilean station was removed to the summit of Mount Montezuma. This station, about 10 miles from Calama, lies in a nearly rainless desert at about 9,000 feet altitude. We have occupied many solar observing stations in far-away desert lands, but Mount Montezuma has proved the best, and is still giving us nearly daily determinations of the solar constant of radiation. Another station on Burro Mountain, N. Mex., was occupied until late in 1946; a third, on Table Mountain, Calif., is still in daily operation.

The variation of the sun's output of radiation, though small in percentage, appears to be a factor of importance in weather. By extensive statistical studies of the quarter-century of nearly daily solar-constant values now available from Montezuma and the other Smithsonian stations, I have shown that the short-interval solar fluctuations of 3 to 5 days in length strongly affect temperatures. The temperature changes are large.

In a recent paper[9] I show that there is a regular periodic variation of solar radiation of 6.6456 days. Its amplitude, not yet thoroughly determined, seems to vary from zero to over 1 percent of the sun's output of radiation. The average magnitude of the variations seems to be about 0.13 percent. Though perfectly regularly periodic as a solar variation, its effects on terrestrial temperature show what, by mechanical analogy, we might call "backlash." That is, they sometimes are 1, 2, or, rarely, even 3 days early or late compared to the average, but rarely change in phase much in the four or five recurrences of each single month. The magnitude of the temperature changes is also variable, but surprisingly large. It ranges from 2° F. to 20° F. Thus these short solar changes are major influences on the weather, hitherto unrecognized because irregular in recurrence to the extent just described. In a test forecast of 36 days, based on the assumption that there would be no change in "backlash" or in amplitude during that interval, the ups and downs of temperature at Washington were correctly predicted as to times, and the average daily difference, observed minus predicted temperature, for 27 days, until a change of amplitude did occur, contrary to the preliminary assumption on which the forecast was based, was 6.6° F. If the causes of

[8] Smithsonian Misc. Coll., vol. 68, No. 3, May 1917.

[9] Smithsonian Misc. Coll., vol. 7, No. 4, Apr. 4, 1947.

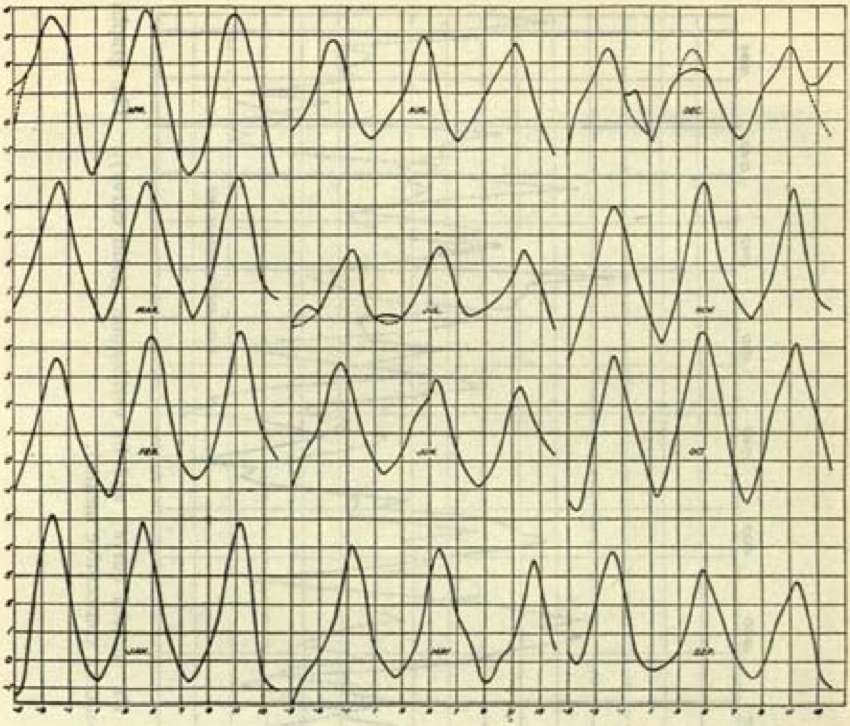


FIGURE 3.—Effect of solar variation of the 6.456-day period on Washington temperatures, all months.

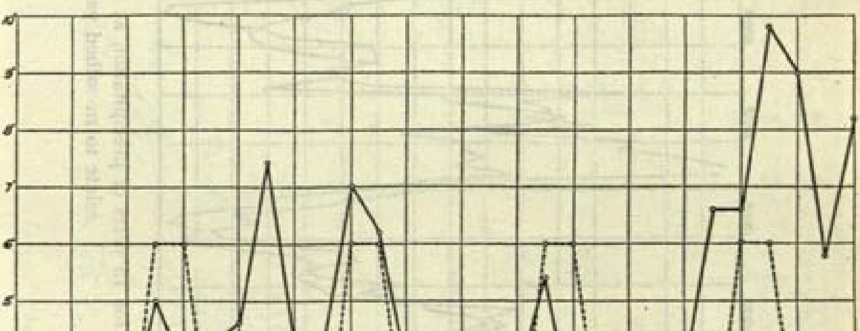


FIGURE 4.—A prediction of Washington temperatures based on the 6.6456-day period (dotted line), and the actual event (solid line).

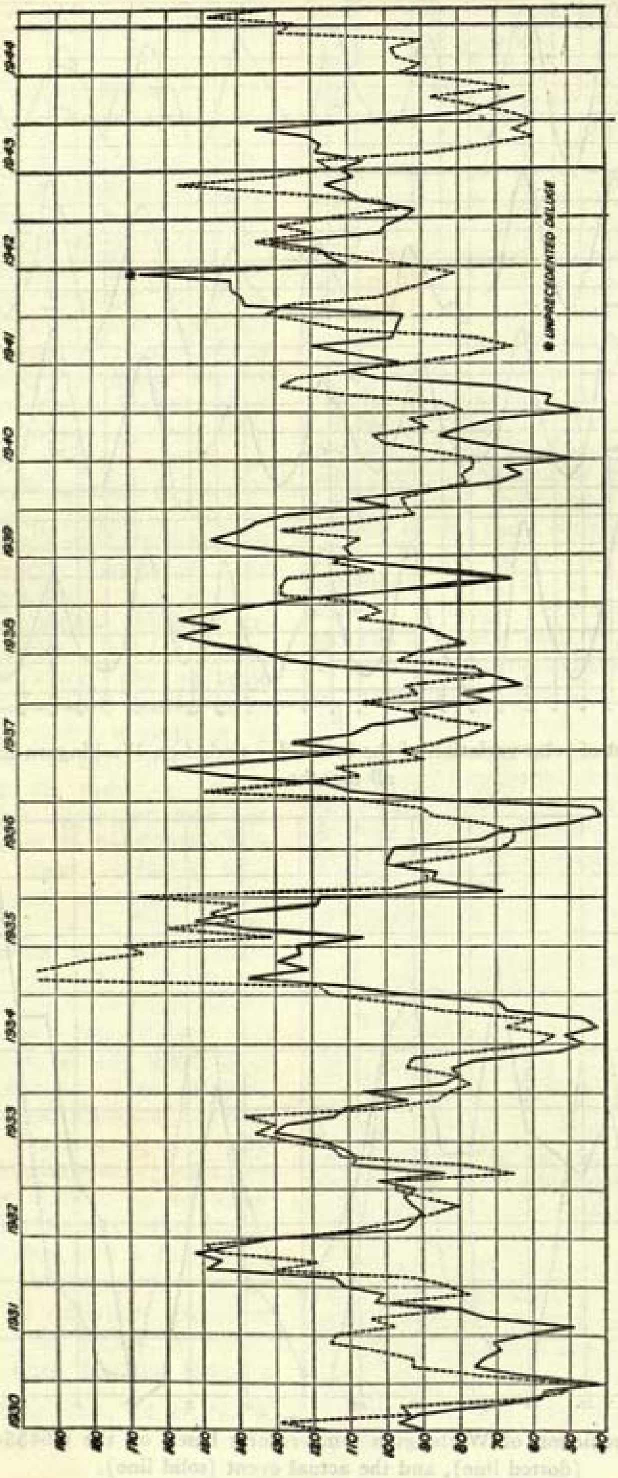
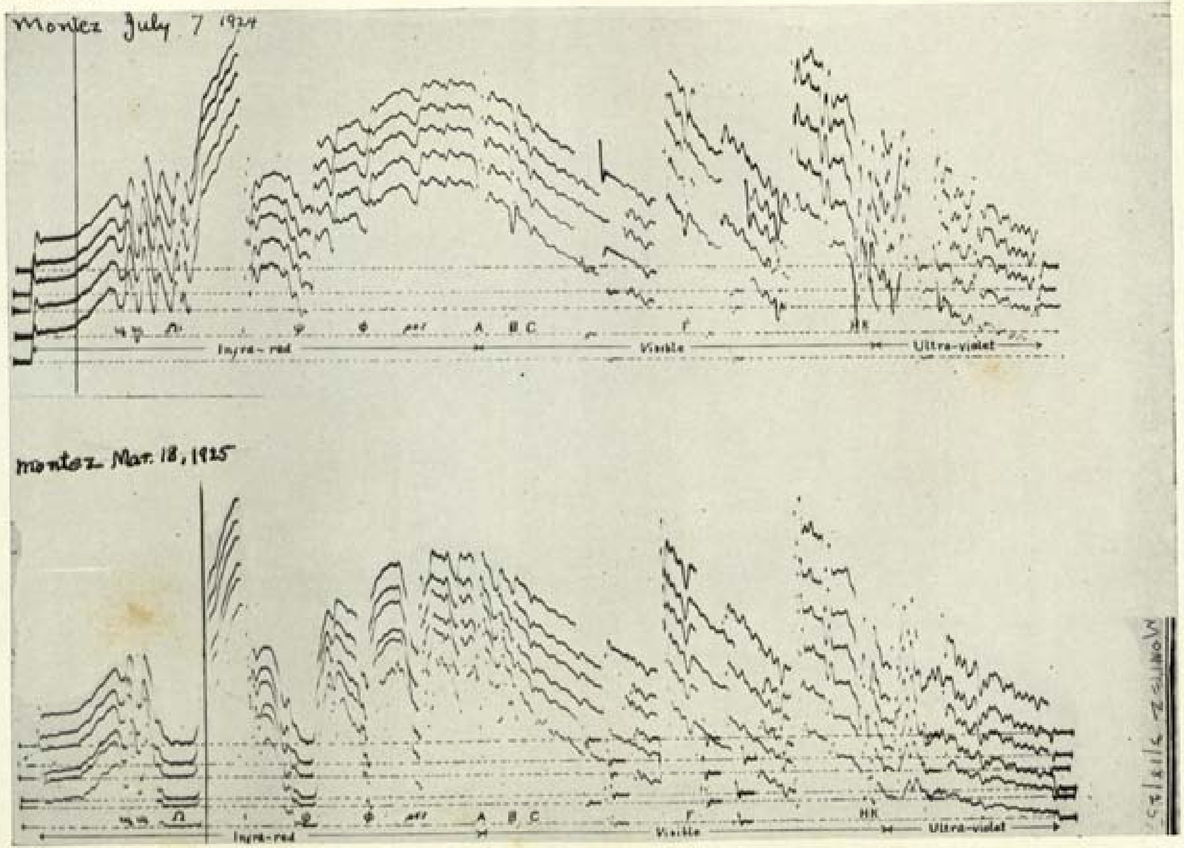


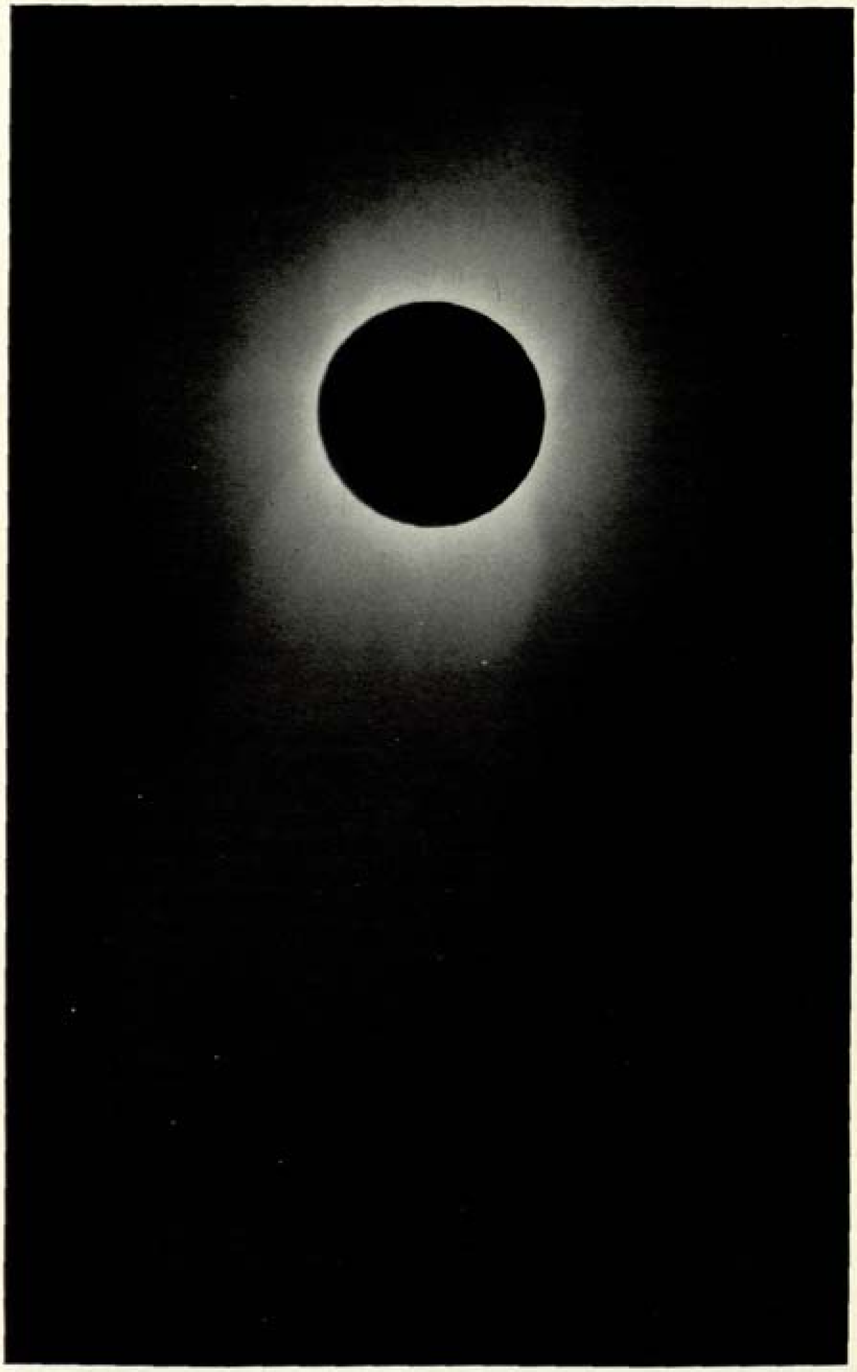
FIGURE 5.—A solar prediction for 15 years of precipitation at Peoria, Ill. (dotted curve) and its verification (solid curve). The graphs relate to smoothed values (5-month consecutive means).



BOLOGRAPHIC ENERGY CURVES OF THE SOLAR SPECTRUM AS MADE EVERY DAY AT SMITHSONIAN SOLAR-RADIATION STATIONS

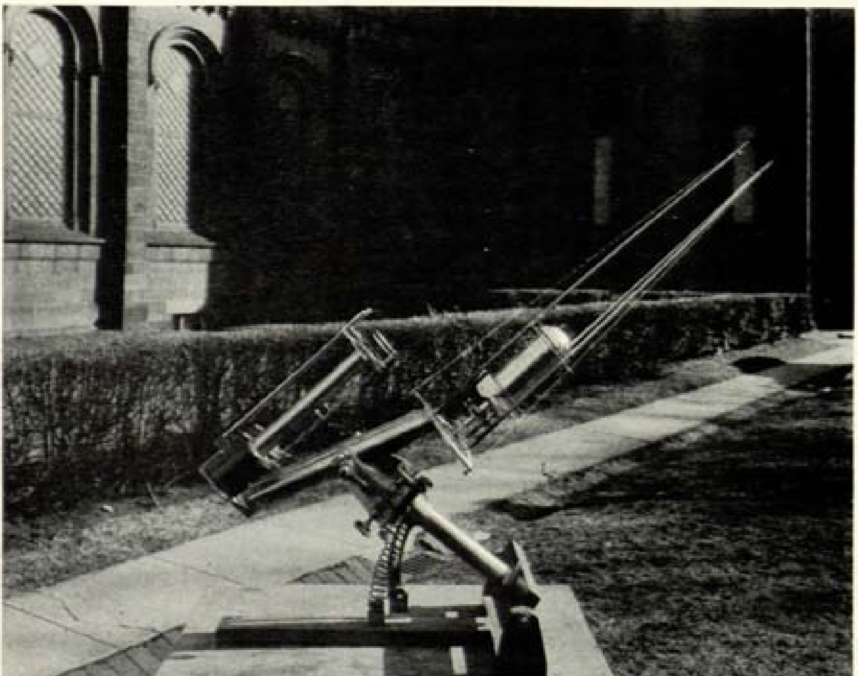
July 7, 1925, a very dry atmosphere; March 3, 1924, a rather humid atmosphere.

DRAWING OF A SUNSPOT GROUP, FROM HIS TELESCOPIC OBSERVATIONS, BY S. P. LANGLEY



TOTAL SOLAR ECLIPSE, MAY 28, 1900

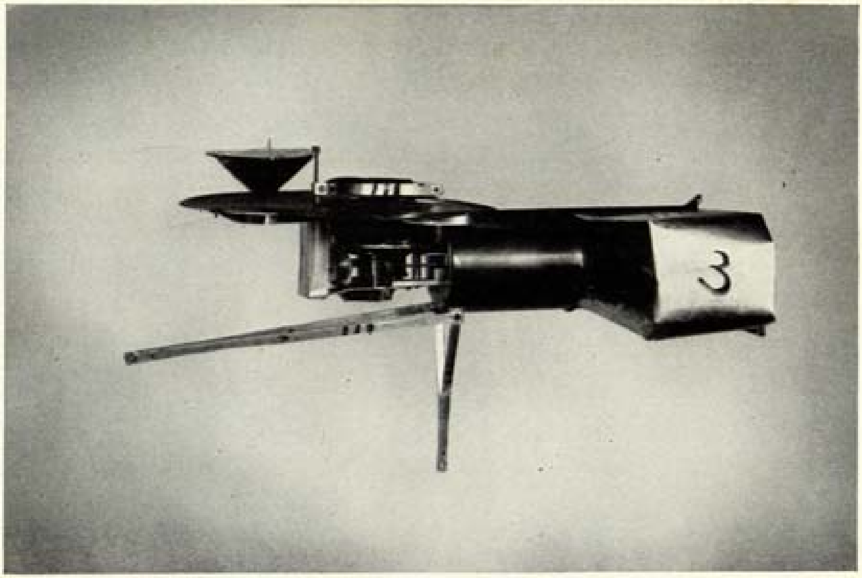
1. THE 60-INCH TELESCOPE DOME AND THE 150-FOOT SOLAR TOWER, MOUNT WILSON OBSERVATORY



2. PYRHELIOMETERS AND PYRANOMETER USED IN DAILY OBSERVATIONS OF SUN AND SKY RADIATION

1. ABBOT'S SOLAR COOKER ON MOUNT WILSON, CALIFORNIA

2. THE SMITHSONIAN OBSERVATORY WITH 40-FOOT SOLAR TOWER, MOUNT WILSON



1. SELF-RECORDING BALLOON PYRHELIOMETER, FLOWN TO AN ALTITUDE OF 25 MILES IN 1914

2. SOLAR-CONSTANT OBSERVATORY OF THE SMITHSONIAN INSTITUTION AT MOUNT ST. KATHERINE, EGYPT

This is at an altitude of 8,500 feet. Spectrobolometer is within the tunnel, and sunlight is reflected in to it.

"backlash" and changes of amplitude can be discovered, the periodicity may prove valuable for long-range forecasting. At least it is an important weather element hitherto unrecognized.

We have shown also that the sun varies simultaneously in no less than 16 periods, ranging from 7 months to about 23 years in length, all nearly integral fractions of 273 months. The 23-year period may be related to the magnetic cycle on the sun indicated by the reversal of magnetic conditions in sunspots during alternate 11-year sunspot cycles. These solar-radiation periodicities are associated with fluctuations of temperature and rainfall. The correlation at some stations is close enough to serve as a basis for long-range weather predictions.

In recent time, L. B. Aldrich, who has succeeded me as Director of the Astrophysical Observatory, has been engaged, in cooperation with the Quartermaster Corps of the Army, in a program of measurements of the intensity of sunlight and of skylight in different parts of the spectrum as it reaches the earth. This is of importance not only to the military, but from the medical point of view. It is hoped to carry on these studies at different stations so as to yield better information as to the influence of latitude, altitude, humidity, and clouds on the sun's rays which affect all life interests.

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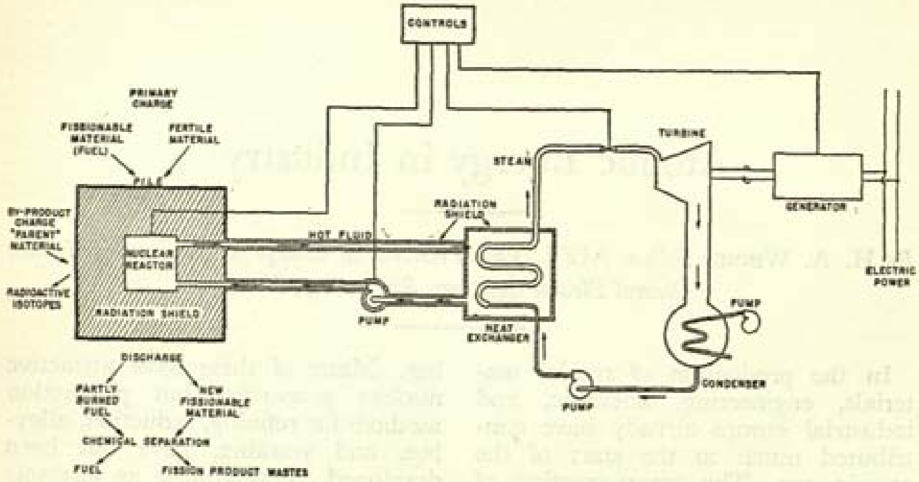

FIGURE 1.—Diagram of atomic power plant.

Atomic Power

As a preface to a discussion of the problems entailed by the use of atomic power, the following broadly reviews the operation of an atomic power plant.

Figure 1 shows schematically a possible atomic power plant. The heart of the plant is the nuclear reactor which generates heat by the conversion of mass to energy. The heat is converted to electric energy by extracting it from the nuclear reactor with a heat-transfer fluid which boils water in a heat exchanger to make steam for a conventional turbine-generator.

The nuclear reactor must be surrounded by an adequate radiation shield to protect power-plant personnel from lethal neutron, gamma, and other radiation. The heat exchanger and primary heat-transfer fluid probably will need a moderate amount of shielding.

Into the nuclear reactor goes the atomic fuel, one of the known fissionable materials such as U235, and if it is desired to generate new fuel at the same time that the charged fissionable material is being consumed, a fertile material, such as U238, also may be charged. A material is called fertile when it can be transmuted to a fissionable material by the capture of neutrons.

Discharged from the pile are the partly burned fuel and the irradiated fertile material which contains some new fissionable material. Later use of the unburned fuel and the new fuel both require chemical separation from any other structural materials, containers, and from the fission product wastes.

An optional phase of operation of an atomic power plant is the production of radioactive isotopes. This is shown in figure 1 as the adding to the pile of a byproduct charge of some "parent" material such as nitrogen, from which a radioactive isotope such as carbon (C14) is produced by the capture of neutrons.

PRINCIPLES OF THE NUCLEAR REACTOR

Occasion frequently may arise for reference to some of the nuclear principles of the chain reaction in the nuclear reactor. They are reviewed briefly in the following.

Energy is released by the fission of the nucleus of a fissionable atom, U235 for example. The two nuclear fragments vary in the number of protons and neutrons contained in each. In general, each fragment is the

nucleus of a radioactive isotope of some element ranging from atomic number 35 to 65.

The two fragments fly apart with tremendous velocities. Their kinetic energy constitutes most of the energy released at the expense of a loss in mass of one-thousandth of the original mass. The fragments will collide with adjacent atoms, giving up energy by increasing the vibration, amplitude, and velocity of the surrounding atoms. Such atomic agitation is recognized as the temperature of the material. Thus the energy appears almost immediately as sensible heat in the fuel itself and within a few thousandths of an inch from where the fission occurred.

Fission was caused by the capture of one neutron by the U235 nucleus. This neutron, when added to the 92 protons and 143 neutrons present, caused the group of particles to become violently unstable and to break immediately into the two unequal fragments.

The entering neutron was the trigger. It has been absorbed and now is lost to the process. If the reaction is to proceed at a constant rate, another neutron must trigger another U235 nucleus, and so on, at equal intervals of time in a continuous chain. The characteristic of U235 (and also plutonium Pu239 and U233) which makes it suitable for such a chain of fissions is that two to three free neutrons are released as part of the debris at fission in addition to the two main fragments. Thus there are available more than enough triggers for the next fission.

The fact that more than one neutron is released per fission permits some losses or nonprofitable absorptions of neutrons without killing the chain reaction (an obvious necessity in practice). The fact that on the average more than two neutrons are released per fission permits several choices in the use of the extra neutrons which are available in addition to the one required for a continuous constant-rate chain reaction. Of course, some of these extra neutrons escape from the reactor and are wasted in the shield or otherwise, but some can be put to useful purpose.

The extra neutrons can be used to expand the reaction, essentially doubling it at each generation. This may result in a bomb. They can be absorbed in a suitable material to produce radioactive isotopes for chemical, biological, or therapeutic use. Of most significance to power, however, is the use of these neutrons to make new fissionable atoms, for example, to transmute U238 to U239 which changes spontaneously to neptunium (N239) which, in turn, changes spontaneously to Pu239. Pu239 is a suitable atomic fuel. Every neutron which can be used in this way replaces the U235 atom burned with a new Pu239 atom and so helps to replenish the atomic fuel supply. Another example of fuel replacement is the production of U233 from thorium.

The neutrons in any nuclear reactor are valuable. Their loss or waste on reactions extraneous to the purpose of the pile is a permanent economic loss. Therefore, pile design for high neutron economy is important.

By controlling the neutron flux, the power output of the pile is regulated. To hold constant power level in a slow neutron pile, rods containing an excellent neutron absorber such as boron or cadmium may be inserted to absorb some neutrons so that equal numbers are available to produce fission at each generation. To increase power, the rods are withdrawn so that a small fraction of the excess neutrons is available at each generation to produce fission. The power then accelerates exponentially. It will continue to accelerate, except for variations in reactivity produced by temperature, expansion of materials, or change of their nuclear properties, until the control rods again are pushed in to absorb the excess neutrons. After the control rods are returned to an equilibrium position the reaction continues at a

constant but higher rate. Power is reduced by the reverse of this procedure.

The time between one generation of the neutrons emitted instantaneously at fission (prompt neutrons) and the next generation is extremely short. This is true even in slow-neutron piles where each neutron is forced to lose almost all of its energy by a multitude of collisions with the light nuclei of the moderator before the next fission. The time is so short that acceleration, even with small changes in reactivity, would be too fast for the control mechanism to be effective were it not that about 1 percent of the neutrons is not emitted promptly at fission, but is delayed from 0.01 second to a minute or more. The delayed neutrons provide a time constant of exponential acceleration long enough to permit control, provided the excess reactivity never is allowed to exceed the margin of delayed neutrons.

The fission products include many radioactive isotopes which give off quantities of very intense radiation, and some of them continue to do so for thousands of years. Provision may be made to contain them within the fuel. If some are allowed to emigrate from the fuel they must be prevented from entering the heat-transfer fluid, or else the fluid system must be designed to handle the accumulated radioactive isotopes.

All the materials in the pile are subject to high neutron and gamma or X-rays which may affect chemical and physical properties. Furthermore, almost all pile materials will become radioactive in greater or lesser degree after extended operation.

DEVELOPMENT OF AN ATOMIC POWER PILE

A scientist or engineer, observing the principles and associated properties of a nuclear reactor, is forced to recognize a number of fields in which extensive research and development work must be done to facilitate the design and construction of a high-performance atomic power system.

First, perhaps, a high-performance system should be defined. Considering land-based plants, proposed primarily for power, a prime consideration is economic use of fissionable materials, including replacement of burned fuel by transmutation. Second, losses in the transformation of heat to electric energy, for instance, should be as low as the current knowledge of materials and processes will allow. This requires temperatures as high as practicable.

Considering how the energy is released, one recognizes that the heat first must be removed from the body of the fuel to its surface. This may entail thermal stresses. It certainly involves a knowledge of the thermal conductivity of the material, and its stability and strength after a reasonable percentage of the atoms have disintegrated into a wide variety of pairs of new atoms. The percentage of the fuel which can be consumed before it must be removed and reprocessed will depend on these factors and also on the neutron physics of the pile because, in general, as the fuel undergoes fission, and the fission products accumulate, the pile reactivity will decrease. The frequency of reprocessing, including its cost and the accompanying losses, may have a profound effect on the economic use of fissionable material.

Such fuel problems cannot be solved by simply consulting a handbook. The metallurgy of fissionable materials is a new and only partially investigated field. Possible alloys and mixtures include many metallic elements which may be valuable because of low absorption of neutrons but which are comparatively new to the metal-processing industries. Conversely, many well-known alloy or mixture components have high neutron absorption and are not suitable. The fuel designer may wish to consider ceramics to obtain very high temperature. If he decides to prevent fission

products from contaminating the heat-transfer fluid, he also must develop a suitable barrier between the fuel and the fluid. This barrier cannot be a heat barrier, so bonding or joining techniques, again using materials which are stable under radiation and which do not absorb too many neutrons, will need investigation. As emphasized by the Smyth Report, this barrier or "canning" problem turned out to be one of the most difficult to solve for the Hanford piles.

Just to develop a fuel which will function in the pile is not enough. The effect of fuel-assembly materials on the cost and efficiency of the chemical-reprocessing plant must be considered. As the whole pattern of atomic power plants, fuel-supply facilities, and fuel-processing facilities develops, national and international security may require centralized reprocessing plants. Standardization of fuel elements also may be a factor. The mechanical form of the fuel preferably should permit charging to and discharging from an active pile, storage and transportation of the radioactive fuel packages with suitable protection for personnel, and so forth.

The purpose of discussing the problems of fuel design so extensively has been to emphasize the many detailed but important research and engineering problems which must be solved on just one component of a high-performance pile. Related problems must be solved on almost all components. The fact that achievement of the probable vast benefits of atomic power entails an integrated and orderly solution of a multitude of problems hardly can be overemphasized. Furthermore, these problems include factors new to design engineers, only recently introduced in scientific research, such as:

1. Material stability under radiation, including physical, chemical, electrical, and thermal properties.

2. Neutron-absorption characteristics of materials.

3. Effect of contamination within the body of the materials by transmutation and fission.

Finally, the experimental techniques for determining many of these nuclear properties of materials are relatively new, some are difficult, some approximate, and in most cases the experimental facilities currently are very limited.

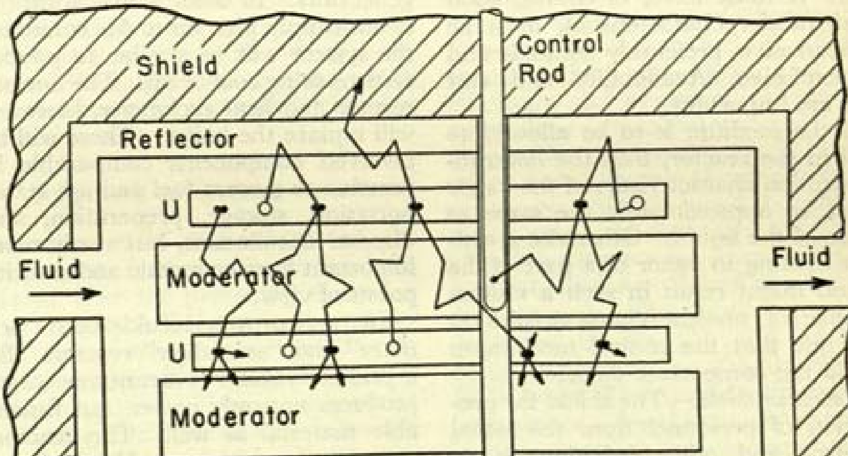

FIGURE 2.—Schematic structure of uranium pile.

It is important to remember too that in the design of the fuel package, and in fact in the design of all parts of a pile, reliability must be achieved to a degree which transcends most of our experience. This is the result of possible radiation hazards from failures, and the extreme difficulty of inspection and repair of a "hot" (in the radioactive sense) pile.

In addition to the problem of fuel design, there are many other features of a nuclear reactor for power purposes which pose some nice questions for engineers and scientists. These are not necessarily less important or difficult than the fuel problems, and involve many of the general considerations and details mentioned in the foregoing. Some of these are reviewed briefly in the following paragraphs.

Heat transfer fluid.—The selection of a fluid to carry the heat from the nuclear reactor to the heat exchanger in which it may be converted to steam or a hot gas is a vital matter. Gases, liquids, and liquid metals all must be considered. The medium must have low neutron absorption. It must be reasonably stable under intense radiation. It must have, of course, good heat-transfer characteristics, must be noncorrosive, preferably nontoxic and nonexplosive. Availability and cost also are important.

If the medium is to be allowed to boil in the reactor, then the neutron-absorption characteristics of the vapor must be approximately the same as those of the liquid. Otherwise a sudden flashing to vapor of a part of the liquid might result in such a sudden change of nuclear characteristics in the pile that the control mechanism could not compensate for it.

Radiation shield.—The shield for protection of personnel from the lethal neutron and other radiations is an absolutely necessary part of any power pile. If research and development can reduce considerably the volume and weight of shield required, it will be very helpful in facilitating the application of atomic power plants to ships, and elsewhere where weight and size are of great importance.

Control.—The reliability of the control system must be absolute, so that any failure must result in safety rather than permit a runaway. It must be able to handle all possible variations in reactivity of the pile, either normal or accidental, gradual or fast, such as result from the slow consumption of the fuel, or the sudden loss of part or all of the heat-transfer fluid. It must be effective at all times, under any possible set of conditions. It must make it impossible for the "nuclear boiler" ever to explode. These requirements are rigid, and *must be met.*

AN ATOMIC POWER SYSTEM

Of what factors might the land-based atomic power system of the future be comprised? In all the discussion on the subject the fact is implicit that at present no possibility is foreseen for obtaining usable electric power directly from an atomic pile. The atomic energy will appear as heat which, when converted into steam or hot gas, will feed conventional turbogenerators. In other words, from the steam-supply pipe on to the consumer the system will be similar to present systems using coal or oil. The nuclear reactor and heat exchanger, however, will replace the boiler. There will be involved components comparable in function to present fuel and ash transportation, storage, preparation, and disposal installations, but vastly more important from economic and security points of view.

The system may inculde both "primary" and "secondary" reactors. By a primary reactor is meant one which produces not only power, but fissionable material as well. The reactors currently operating at Hanford, inasmuch as they produce heat (at present dissipated in the Columbia River) and plutonium, are by this definition primary reactors. Under the international control plan proposed

by the United States to the United Nations such reactors would be under the control of an international authority.

By a secondary reactor is meant one which consumes but which does not produce fissionable material. If the fuel charged into such a reactor is "denatured" so that it could not be converted easily to bomb use, the international control plan would permit such a reactor to be under national or private authority.

The system would include a chemical-reprocessing, or fuel-reclamation, plant. When the fuel in the reactor has reached a certain state of depletion, it will have to be removed and passed through a remote-controlled shielded process for removal of the fission products, and put into suitable form for further use. Here again the international control plan would require operation by the international authority because of the possibility of diversion of atomic fuel.

It is obvious that consideration of national and international security will have a large bearing on how such operations will be conducted, how fuel will be stored and transported, even on geographical location of plants.

Here again there are many factors which will have a profound effect on future developments, factors which today cannot be evaluated with any degree of accuracy.

ECONOMICS OF ATOMIC POWER

Treatment of the subject of the economics of atomic power has been placed after the preceding discussion purposefully. Estimates of economy and cost of atomic power sufficiently accurate to predict where or when or if atomic power will be in competition with other fuels do not appear feasible in view of the multitude of unknown technical and economic factors which will be established only as research and engineering produce results. However, the long-term future prospects for competitive and economic atomic power look bright. The magnitude of the potential ultimate gains to society are so great that research and development must proceed vigorously on a wide front.

The following quantitative statements can be made with a considerable degree of accuracy.

As an atomic power station or system will be similar to a coal- or oil-fired station in all parts from the turbine steam pipe on to the consumer, the investment and operating costs for this part of the station will be essentially the same as for coal or oil.

The nuclear reactor and heat exchanger in an atomic plant probably will have a somewhat higher first cost than the boiler installation in an ordinary steam plant. Thus it is probable that an atomic plant's opportunity for reducing cost of power to the consumer lies in the cost of fuel only. In modern public utilities, cost of fuel represents, on the average, only about 20 percent of the total cost of power to consumers, so atomic power can affect only this percentage of the total cost to the consumer.

Some of the significant unknowns, or unavailable data, which make it impossible to estimate accurately the over-all cost of atomic fuel today are first cost of atomic fuel in suitable concentration and form; cost and efficiency and frequency of chemical extraction, reprocessing, and final preparation; plus waste disposal; all of which are ultimately chargeable to the consumer. Also included, but on the credit side, are the gains from sale of radioactive tracers, byproducts for research, and use of facilities for test and research. These latter gains are estimated by the Carnegie Endowment Committee on Atomic Energy (2) to be small compared with revenue from power. Another unknown factor is the extent to which national or world interest may require the production of fissionable material by national or international authority for any reason, and perhaps regardless of cost In this event, atomic power is a by-

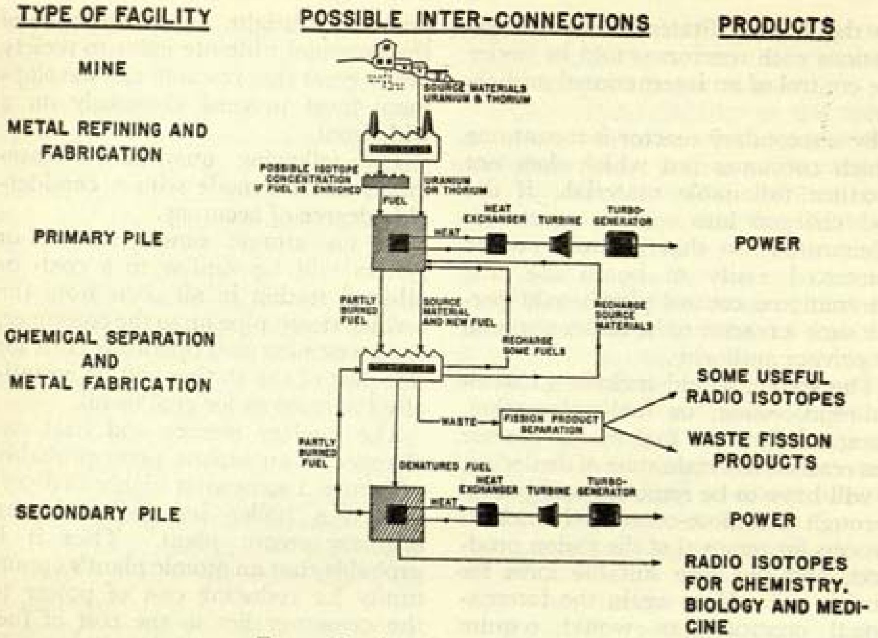

FIGURE 3.—Atomic power facilities.

product and its production and sale at competitive rates simply replaces expense for cooling otherwise required by such installations and pays for some, perhaps all, of the cost of the plant and its operation.

APPLICATIONS OF ATOMIC POWER PLANTS

There has been much speculation, some of it unwarranted, as to possible uses of atomic power.

The heavy protective shielding required on any such plant precludes its use where extremely light weight is required. The shield would crush an automobile or a truck. Atomic power on inhabited aircraft is extremely unlikely, at least for a long time.

It ultimately may prove possible to design an atomic plant for a locomotive, although it does not look feasible at present.

Atomic plants for naval and large commercial ocean vessels appear definitely possible, and also attractive from the standpoint of making refueling extremely infrequent. This well may be the first real commercial application.

Atomic power plants for land use certainly are feasible technically, and probably will be attractive first where fuel is scarce and high in cost.

Thus far this article has been devoted to a discussion of power as distinct from industrial uses and benefits of other aspects of atomic energy, tracer chemistry, radiation chemistry, and so forth. These are reviewed more briefly in the following. Such emphasis should not be construed as an opinion that power is any more important to industry. Other benefits may prove more important in the generations yet to come; current estimations of the time that must elapse before any authoritative evaluations can be made range all the way from 10 to 40 years.

Radioactivity and Radiation

In discussing the following phases, the authors have drawn much upon published material (2–4), particularly the predictions of future possibilities in these fields by such authorities as Doctors Arthur H. Compton, Zay Jeffries, James Franck, and Milton Burton.

INDUSTRIAL USE OF RADIOACTIVITY

The prime characteristics of radioactive tracers which make them of value are two. First, extremely small quantities can be detected by registering the particles or radiations emitted at each disintegration on a suitable radiation-detection instrument. Second, by the same means it is possible to detect and to measure the amount of tracer present quite accurately without removing it from the compound by chemical separation or even without removing or sampling the compound from its process container.

Perhaps the surest widespread industrial uses are in the chemical laboratories. Because chemically and physically the radioactive isotope of an element acts exactly the same as the stable isotope of the same element, analytical techniques can determine the amount of a given element in the final product or at an intermediate stage if a known amount of radioactive isotope of that element is added to the bulk at the start. This can be of value when quantitative analysis or spectrographic methods cannot be used.

Some of the scientific advice given to the United Nations Atomic Energy Commission by the Office of the United States Representative, which has not received wide national circulation, is quoted (3):

> The availability of a variety of radioactive tracer elements will afford possibilities for answering questions hitherto difficult to answer. By the use of instruments sensitive to radioactivity, the radioactive atoms of a given element, which always travel with their nonradioactive brothers, may be used as indicators of the travel of the latter, a phenomenon often difficult to follow by ordinary methods. Particularly important are questions as to how, and how fast, atoms transfer from one molecule to another or from one place to another in the course of a chemical process, including such processes as corrosion, diffusion, absorption of molecules on surfaces, and formation and destruction of colloids.
>
> The use of radioactive tracer atoms holds much promise for the study of the composition of liquids and vapors in equilibrium with each other, and for studying the performance of distillation columns and other equipment used in chemical engineering, for example, in the oil industry. Particularly important as a tracer in the oil industry and wherever carbon compounds are concerned will be the carbon isotope C14.
>
> The radiations from the fission chain reaction are capable of inducing chemical reactions which cannot ordinarily be carried out, since one effect of radiation is a sort of catalysis of thermodynamically possible reactions.
>
> METALLURGY
>
> In metallurgy, the use of radioactive tracers has many possible applications. Some of these are as follows:
>
> 1. Diffusion of an element into itself and into alloys in which it is a component could be followed if the diffusing atoms are radioactive.
> 2. Inclusions could be identified by adding a radioactive form of a suspected component to the melt and photographing by microradiographic techniques.
> 3. Positive identification and location of minor constituents, which often markedly affect the properties of metals and alloys, could be made by microradiographic methods; such information is usually very difficult to obtain by microscopic methods.

The previous discussion has envisaged adding the radioactive tracer to the material. A very different analytical technique is based on producing radioactivity in all susceptible elements of a sample by subjecting the sample to a known amount of radiation in the neutron flux of a pile. Then the presence of minute traces of impurities can be identified by observing the half-lives and type of radioactive emanations after removal from the pile. The amount of impurity also can be estimated.

Tracers may find widespread use in production processes. Here, however, additional limitations enter. Cost in repetitive use becomes more significant. The Carnegie Endowment Committee on Atomic Energy (2) estimated that for radioactive carbon (C14) to be attractive to industry, it should be produced at about $500 per gram to reach mass use in petroleum, coal tar, and similar large-volume production. This assumed that a milligram (50 cents) could tag a ton of material at an additional cost of 50 cents for incorporating the tracer

in the process, making the total cost \$1 per ton. The 1946 price of C14 from the Manhattan District was about \$400,000 per gram.

The committee estimated that the market might pay about \$10,000 per gram for C14 used in bulk organic chemicals, and \$100,000 per gram for use in pharmaceuticals.

Actual use, however, may develop unexpected advantages, and of course cost is bound to decrease as production increases.

Another critical problem in production as distinct from laboratory use is the question of widespread distribution of all types of products and materials containing traces of radioactivity and the effect on sensitive materials such as photographic film, and on living things as a result of continual intimate exposure or possible ingestion by unwarned people or animals. Some believe that this problem will limit production uses to those isotopes with short half-lives of perhaps a few days. Then a period of storage of products before shipment could eliminate virtually all radioactivity. Such considerations may limit the list of possible tracers. For example, C14 has a half-life estimated at 6,000 years. Two other carbon isotopes, C10 and C11, have impractically short half-lives of 8 seconds and 20 minutes respectively. Thus no carbon radioactive isotope is known which could be used if radioactivity of the product is objectionable. Such questions can be settled only as experience and knowledge is gained and when proposed uses are specific rather than hypothetical. The need for elements with short half-lives either in production process or laboratory well may require a wide distribution of isotope-production facilities near industrial and population centers.

It is also possible that experience will show that the amount of radioactivity required for tracer purposes in many products is so small that long-half-life tracers can be used widely in metallic, organic, and other materials. Then industry may be faced with radioactivity in materials purchased for further processing, in scrap for remelting, and so forth. Such background radioactivity, if not controlled, might interfere with the further use of tracers. Thus in years to come materials specifications may be found containing minimum tolerances for radioactivity.

The number of industrially important elements for which potentially useful radioactive isotopes, those with half-lives longer than a half day, are not known is quite limited but includes oxygen, nitrogen, magnesium, aluminum, and silicon.

There are some production uses which do not require presence of the radioactive isotope in the product. Included are separation processes where the radioactive isotope is one of the elements rejected, also processes involving catalysts.

For example, in some oil-refining processes, a catalyst is diffused through a reaction vessel. Certain malfunctions may cause it to segregate or to emigrate from the vessel. If the catalyst were tagged with a radioactive isotope, its concentration and location could be registered continuously through the walls of the tank.

RADIATION CHEMISTRY

The infant field of radiation chemistry relating to the use of radiation to produce or catalyze chemical reactions is perhaps too new to warrant extending speculation very far. However, the use of ultraviolet radiation to produce vitamin D in ergosterol is a well-known and related reaction.

Doctors Franck and Burton (4) have examined the possibilities and reported to the United Nations the following "groups of processes where application of radiation chemistry appears promising":

> We may anticipate economic advantages in the vast field of polymerization processes which are now so successfully applied in the manufacture of plastics, rubber, and so forth; in this field, in fact, initial successes

already have been obtained. In a similar connection, studies even prior to the war on the effects of radiation on some of the constituents of natural gas indicate that they may be converted, via the medium of radiation chemistry, into industrially important products. Their present uses (for example, in the production of carbon black or for fuel) are economically unsound. Related to such processes in a certain sense is the low-temperature cracking of oils, which should be intensively studied. Radiation chemistry here presents the opportunity of a new technique which may produce new and very interesting products.

A host of rare but medically important drugs, until now synthesized only by plants but not *in vitro* (in the test tube) probably will be by-products of the utilization of radiation chemical processes. Very interesting preliminary photochemical effects on viruses have been reported; viruses may be made to lose their virulence while still retaining their ability to produce antibodies. Progress in this important field is limited by the lack of penetration and the specificity of the rays which must be used; radiation chemistry should promote such work at an accelerated pace. The chemical aspect of the large field of biologicals is a portion of the field of radiation chemistry which we are now just beginning to tap. Some notion of the vistas which lie before us, when we begin to understand primary effects a little better, is indicated by the suggestions of the medical use of specifically absorbed radioactive dyes and of the possible large scale production of vaccines.

In the fields of inorganic chemistry and physics the production of new phosphors and of inorganic polymers should be studied. Possible hardening of metals by radiation and a host of new enterprises made possible by the interesting process of dislocation of atoms in solids may become important.

In this field, chemists point out that often, when a reaction is discovered by the use of radiation, continued investigation leads to thermal or catalytic means to make the reaction "go." In general the latter are much cheaper for production. Such progress does not, however, minimize the significance of an original discovery using radiation to produce the reaction.

In the field of such ultracomplex molecules as antibiotics such as penicillin and streptomycin new and improved strains often are cultivated from mutations. Radiation may be a tool which can produce a variety and extent of mutations in such molecules of many times the diversity and rate at which they occur in normal evolution.

Chemists may learn much about the stability of chemical bonds by breaking them with alpha, beta, gamma, or neutron radiations. While such radiations have been known for many years, they have been available only in the form of a few rare natural radioactive materials or in connection with the limited output of "atom-smashing" accelerators. The vast spectrum of radiation intensities now beginning to become available makes widespread research in these fields possible.

Future Possibilities

A great many of the statements in this article of necessity are hedged with "if," "but," "possibly," or "probably." This fact merely emphasizes the newness of the field under consideration and the tremendous possibilities ahead.

Atomic energy is not producing commercially useful power as yet, although such production is technically possible. It is probable that one or more experimental or demonstration plants will be in operation within the next 2 to 4 years.

Such production appears economically feasible, at least for many special applications. However, the development of economically competitive atomic power promises to be a long-term project, possibly requiring decades. And its advent will be gradual. It is the author's belief that atomic power will supplement, but not supplant, present power sources.

What may be termed the by-products of atomic energy—radioactive isotopes, radiation chemistry and metallurgy, fission products—well may prove of more importance to society than atomic power itself, and many of their benefits probably will be realized more quickly.

It is quite evident that in order to reap all the potential benefits, a tremendous amount of research and

development must be carried on. There is no doubt but that it will be done.

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High-Altitude Research with V–2 Rockets[1]

By Ernst H. Krause, *Naval Research Laboratory*

[With 6 plates]

The study of the heavens is an ancient science. It began with speculation about the movement and constitution of the sun; later it moved into the greater universe of the stars (1);[2] and more recently it expanded into that small but very interesting region of space represented by the earth's atmosphere (2). It seems fitting that a review of the more modern aspects of this subject should be made here since Franklin himself, the founder of the American Philosophical Society, made some of his more important contributions to science in this field (3).

The atmosphere of the earth is a very complex affair. Many things are known about it and yet the over-all picture is beclouded by lack of sufficient information of the various mechanisms involved to tie all the observed phenomena into one unified picture. The presence of the lower atmosphere makes the study of phenomena in the upper atmosphere very difficult and in many cases impossible. Similarly, the existence of the atmosphere sets very definite limitations on studies in such fields as astrophysics and cosmic rays, while on the other hand the atmosphere provides us with many new phenomena to study, such as the ionosphere, the aurora, etc.

The answer to many of these difficulties is to study the phenomena within the atmosphere at those points where they occur and to make astrophysical and other studies from above the atmosphere. A step in this direction was the exploitation of the balloon as a vehicle. The balloon, however, has two serious shortcomings. First, it has a maximum ceiling between 30 and 40 km. Many observations have been made up to these altitudes by means of balloons, but a great deal of data is desired above these altitudes. Second, the payload capabilities of balloons are limited to the order of 100 pounds, unless one makes use of complicated balloon formations or of very large balloons such as were used in the *Explorer* flights (4, 5). Both of these difficulties can be solved by the use of rockets which are not limited in ceiling, and, although there are payload limitations, the problem of carrying 1,000 pounds to altitudes of 200 km. or more is perfectly feasible.

Although rockets themselves date back many centuries, the utilization of one which would carry sufficient weight to conduct an experiment did not seem practical up to the beginning of the last war. However, with the advent of the war, a tremendous impetus was given to rocketry because of its usefulness as a military device, so that several rocket-powered vehicles emerged from the war which could reach altitudes greatly in excess of any that had been reached before. Of these devices, the V–2, designed and built by the Germans, was well out in front. Not only did it reach altitudes much greater than any

[1] Read April 25, 1947. Reprinted by permission from Proceedings of the American Philosophical Society, vol. 91, No. 5, December 1947.

[2] Numbers in parentheses refer to literature cited at end of article.

previously attained by rockets or by other means, but it also was sufficiently large that it could carry a payload much greater than any research worker had hoped for.

The work on the upper atmosphere utilizing the German V–2's in this country has been going on for a little more than 1 year. Even in so short a time it can be stated that the V–2 has already made important contributions to such fields as solar spectroscopy, cosmic rays, and the measurement of atmosphere pressures and temperatures (6, 7, 8, 9). To those of us in the field, it is somewhat surprising, but nevertheless gratifying that the early experiments have proved so successful. We had anticipated that the complexities involved in perfecting the necessary new techniques could easily have consumed the first year's work.

First, I would like to say a few words about the organization of a project as large as this. There is no one organization that encompasses the entire project. The V–2's themselves are assembled, made ready to fire, and fired by the Army Ordnance Department with the aid of the General Electric Co. under a special contract for this purpose. Once the V–2 has been fired, it is of course very important to know where it is at all times in its trajectory, so that data taken can be correlated against altitude, range, etc. The ballistics and the problem of tracking in general, involving many types of radio, radar, and optical methods, are the responsibility of the Ballistic Research Laboratories of the Aberdeen Proving Ground.

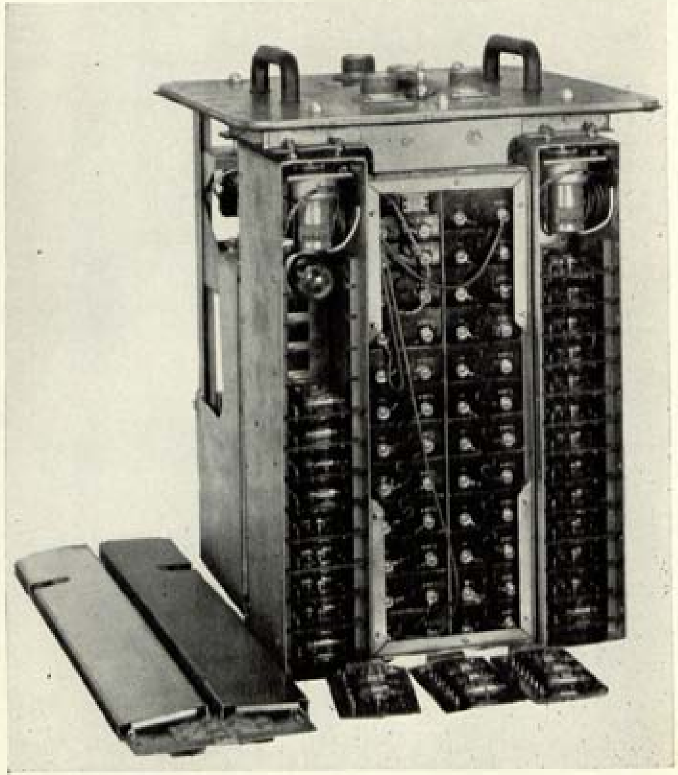
The actual upper-atmosphere work is conducted by various institutions including the Air Matériel Command, the University of Michigan, Watson Laboratories, the Applied Physics Laboratory of the Johns Hopkins University, the Signal Corps, and the Naval Research Laboratory. In addition, there are numerous other contributing agencies, including Princeton University, the National Bureau of Standards, Harvard University, and the California Institute of Technology. All the work is coordinated through a V–2 Panel which consists of members from most of the above-named institutions and agencies.

The V–2

Just to refresh your memories I might point out a few of the characteristics of the V–2 (10). Plate 1, figure 1 shows the V–2 on its launching patform. It stands about 46 feet high, has a total weight of 28,000 pounds when fueled and 9,000 pounds empty. The total weight of payload carried is about 2,000 pounds. Its diameter is 65 inches. Stabilization is accomplished by a set of carbon vanes placed in the jet, aided by a set of air vanes in the fins. Fixed gyroscope stabilization is maintained in azimuth, and a gyroscope program control feeds a predetermined tilt program to the fins. When the rocket motor is started, the rocket begins to rise slowly as soon as the acceleration due to the thrust exceeds 1 *g*. Since a rocket motor of this type is a constant-thrust device and since the mass is constantly decreasing owing to fuel consumption, the acceleration gradually increases until after about 60 seconds it reaches a value of 6 *g*. At this point the fuel is completely consumed, the missile is out of the denser atmosphere and it proceeds on a trajectory which is a function only of its position and velocity at the time of fuel burn-out. Up until the time of burn-out it is, as previously pointed out, completely stabilized. Thereafter, since it is out of the atmosphere and since no more jet power is available, no further stabilization is obtained. The result is that any accidental angular momentum imparted during the fuel burn-out period produces a roll, pitch, or yaw during the remainder of the free-space flight. Here we encounter the first objectionable feature of the V–2 rocket as a research vehicle. We find that, in general, there is a very definite roll about the rocket's longitudinal axis

1. V-2 ON ITS LAUNCHING PLATFORM

Note the camera opening in the midsection and also the special painting on the warhead to facilitate recovery.

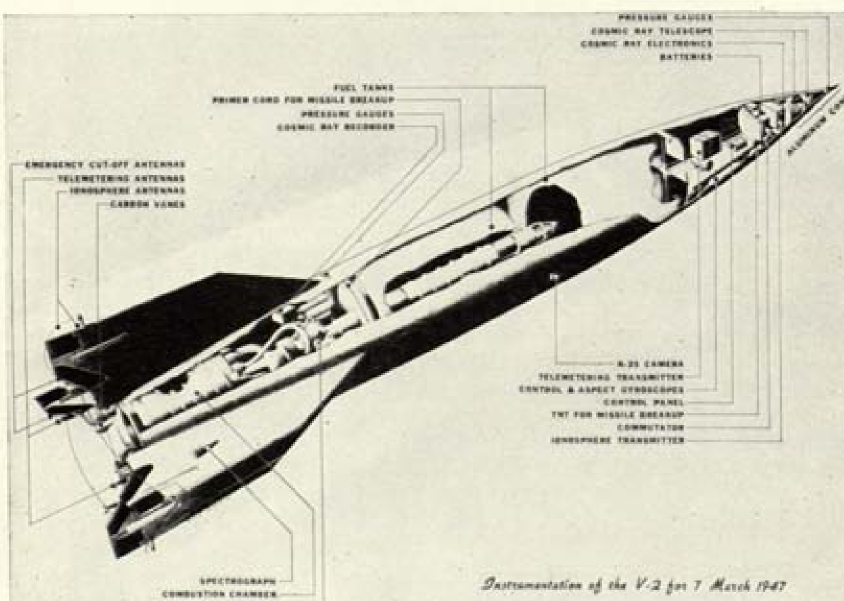


2. TELEMETERING TRANSMITTER REMOVED FROM ITS PRESSURIZED CONTAINER

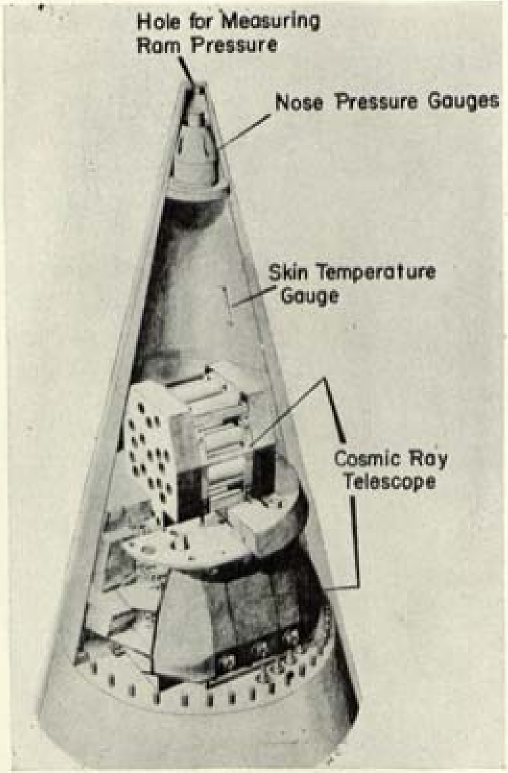
The circuitry for each of the 23 channels can be quickly unplugged for servicing. The two motors at the top are used for periodically transmitting calibrating voltages while in flight. Note the almost exclusive use of subminiature tubes.

1. V-2 After Impact

The chances of recovery of film cartridges and other recorded data from the missile after impact are very good.

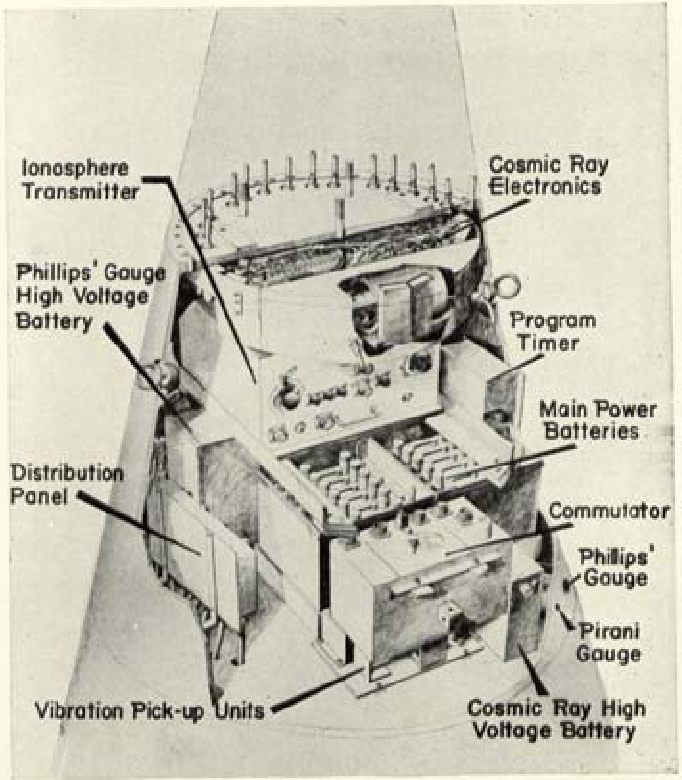


2. Cutaway Sketch of the V-2 as It Is Used for Upper Atmosphere Research



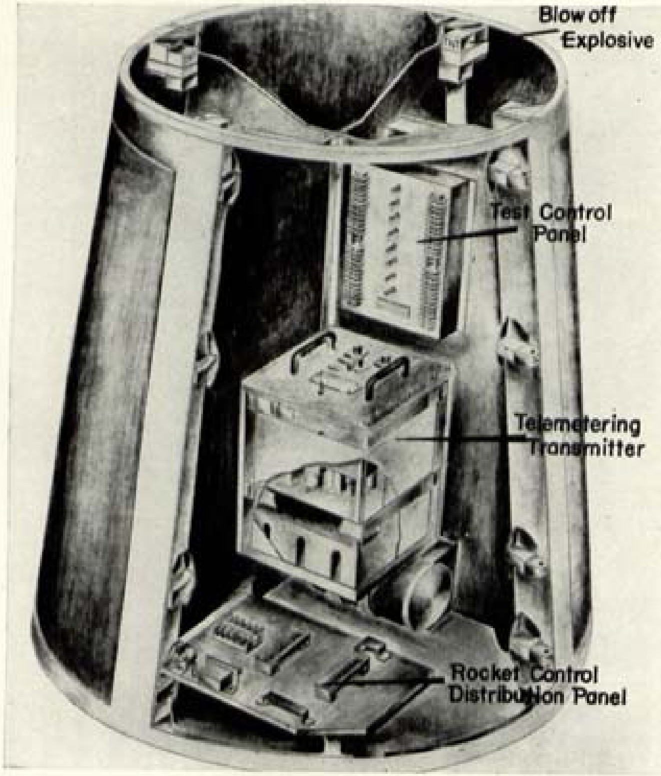
1. SKETCH SHOWING THE FORWARD SECTION OF THE WARHEAD

Includes ram pressure gauges, skin temperature gauges, and cosmic-ray telescope.



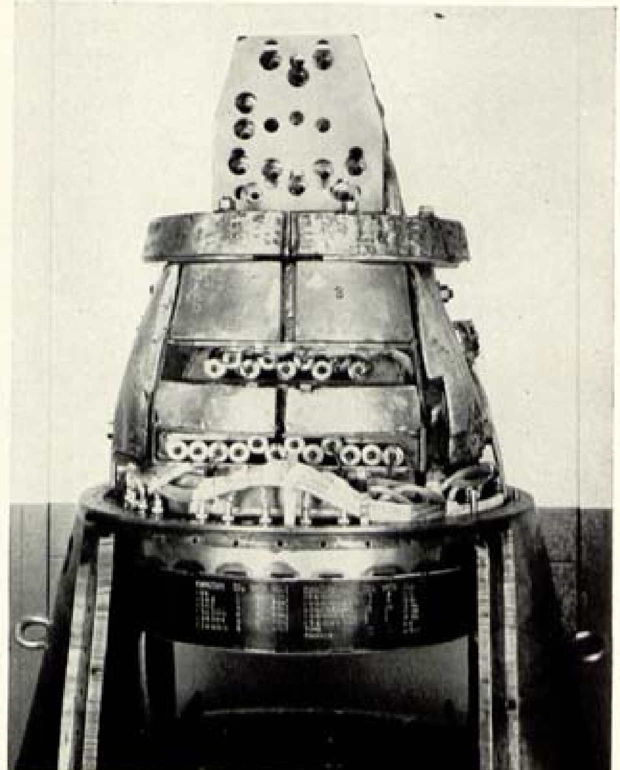
2. SKETCH SHOWING BOTTOM HALF OF WARHEAD

Includes cosmic-ray electronics, ionosphere transmitter, various pressure gauges, and miscellaneous equipment.

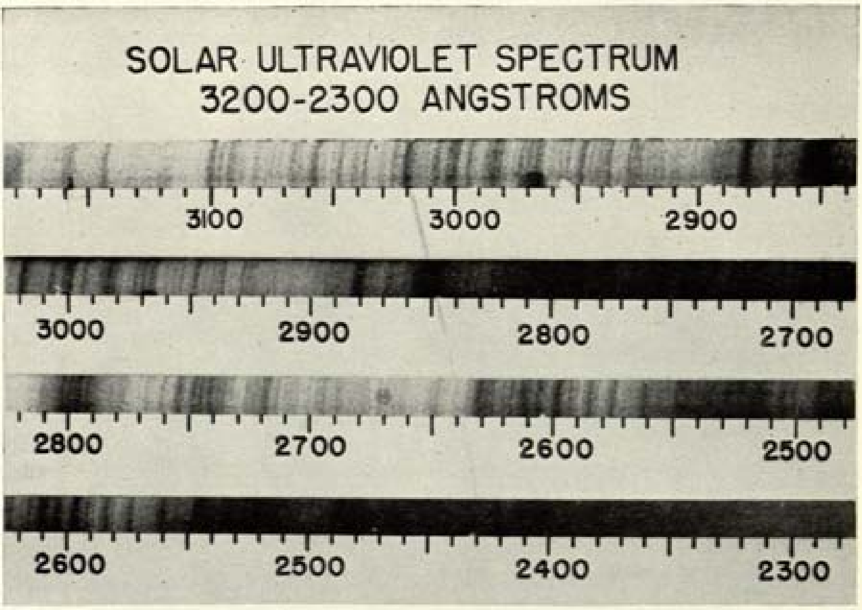


1. SKETCH SHOWING CHAMBER BELOW WARHEAD

Includes telemetering transmitter and distribution panel.

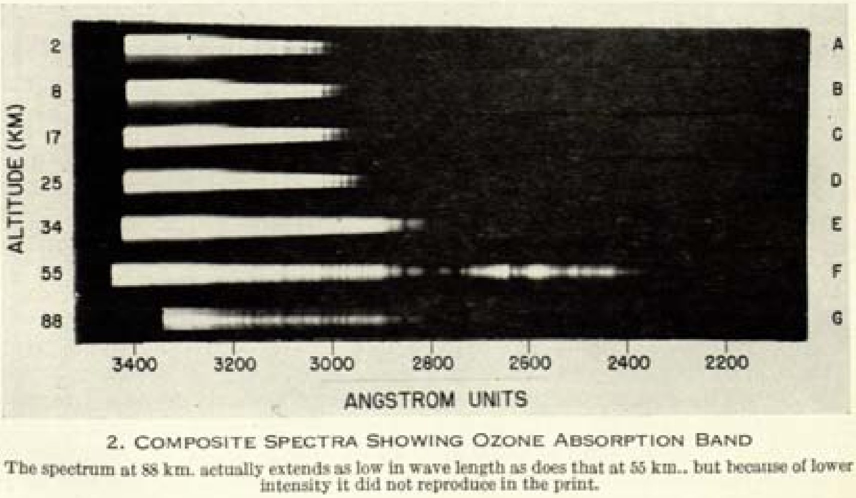


2. PHOTOGRAPH OF COSMIC-RAY TELESCOPE IN MARCH 7, 1947, MISSILE



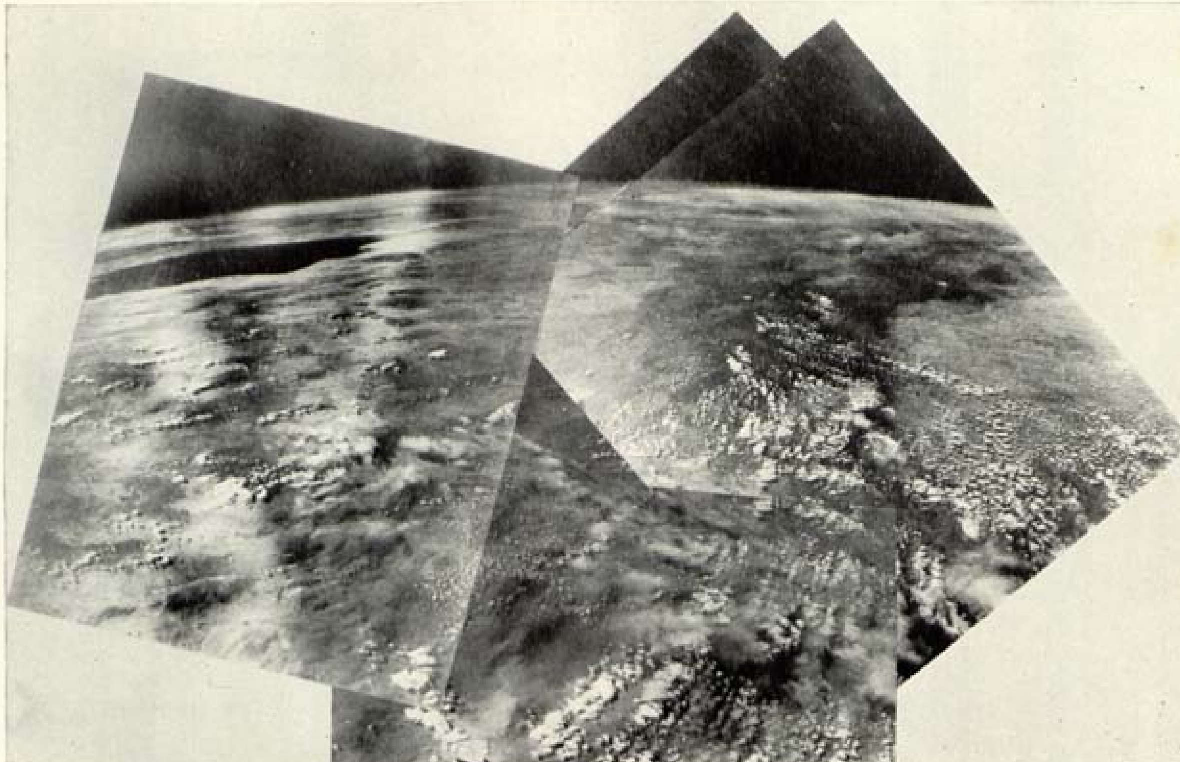
1. FRAUNHOFER SPECTRUM OBTAINED IN THE MARCH 7, 1947, MISSILE

This is the first time the region below 2900 A. has been photographed with such high resolution.



2. COMPOSITE SPECTRA SHOWING OZONE ABSORPTION BAND

The spectrum at 88 km. actually extends as low in wave length as does that at 55 km., but because of lower intensity it did not reproduce in the print.



A COMPOSITE PICTURE MADE UP OF THREE SEPARATE PHOTOGRAPHS TAKEN AT AN ALTITUDE OF 162 KILOMETERS (101 MILES)

This picture covers approximately 500,000 square miles of southwestern United States and northern Mexico. The photographs do not match exactly owing to the varying camera angles.

over most of the trajectory. In addition there have been cases where a definite yaw and pitch have been observed. The exact knowledge of the missile's attitude after burn-out is not complete at present but is the subject of an intensive study.

Figure 1 shows the trajectory of the V-2 as it was plotted for a firing on March 7, 1947. A study of this trajectory brings out a second shortcoming of the rocket in general, that is the short time that it spends in free space. It can be seen, for example, that the time the rocket spends above 50 km. is about 5 minutes. It is therefore necessary to complete all experiments in this limited time.

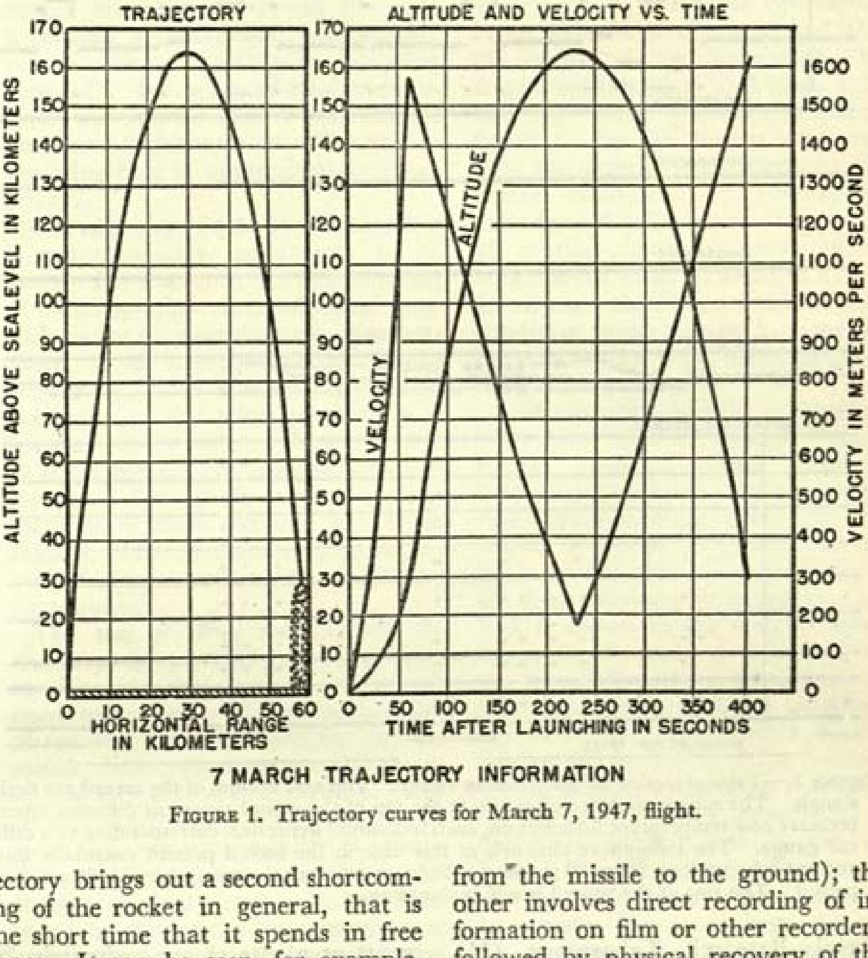


Figure 1. Trajectory curves for March 7, 1947, flight.

To conduct work in the V-2 it was necessary to design and build a special warhead with access doors for installing and adjusting the equipment. It is not a standard device but usually undergoes special modification for each flight, depending on the particular experiments involved.

Data Recovery

Two general methods of data recovery are used. One involves telemetering (radio transmissions of data from the missile to the ground); the other involves direct recording of information on film or other recorders, followed by physical recovery of the equipment after impact.

Of these two general methods by far the more successful has been that of telemetering. The telemetering system which has been employed in all V-2 firings is a 23-channel pulse time modulated system designed at the

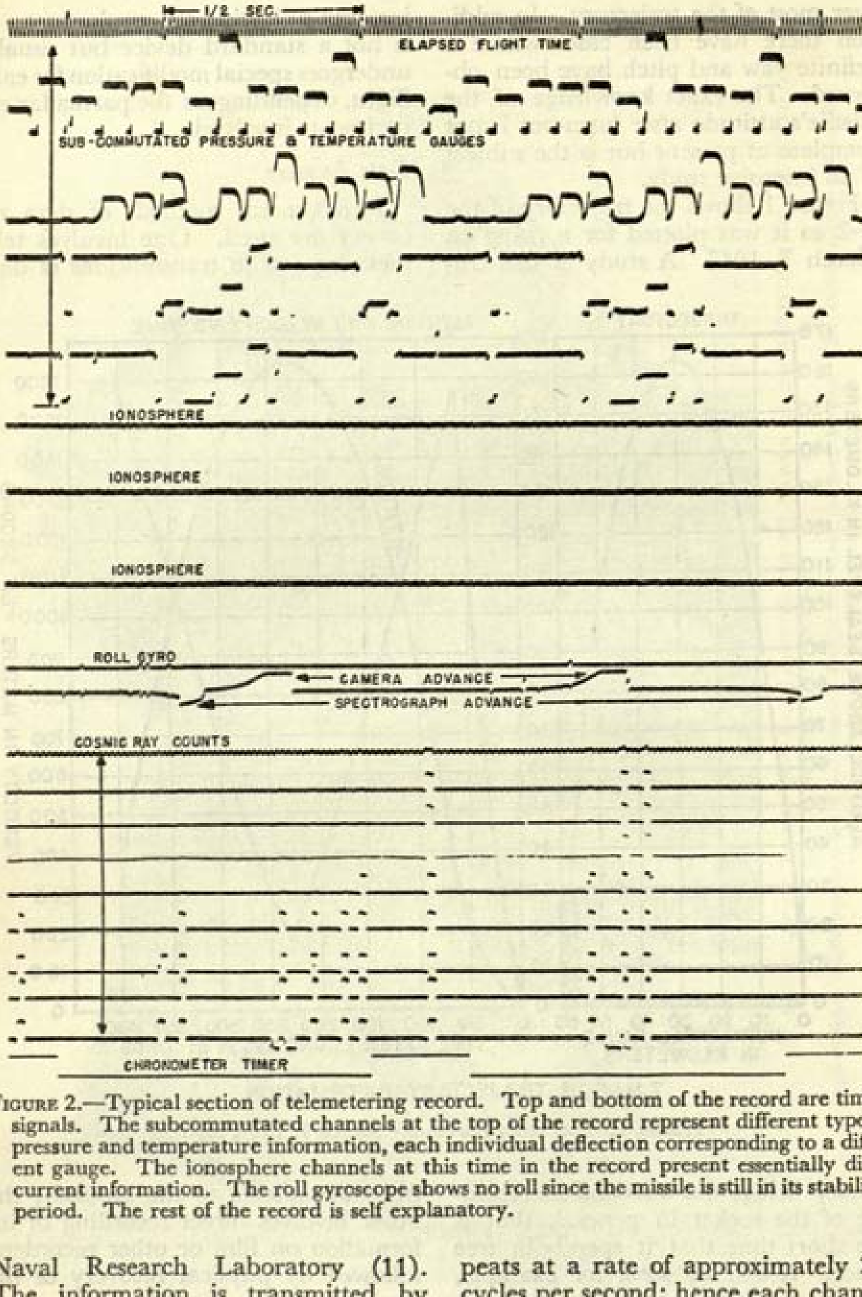


Figure 2.—Typical section of telemetering record. Top and bottom of the record are timing signals. The subcommutated channels at the top of the record represent different types of pressure and temperature information, each individual deflection corresponding to a different gauge. The ionosphere channels at this time in the record present essentially direct current information. The roll gyroscope shows no roll since the missile is still in its stabilized period. The rest of the record is self explanatory.

Naval Research Laboratory (11). The information is transmitted by means of a group of pulses such that the intelligence on any given channel is contained in the spacing between two adjacent pulses. Twenty-four such pulses constitute one group for a 23-channel system. The group repeats at a rate of approximately 200 cycles per second; hence each channel is sampled at this rate. Plate 1, figure 2 shows the complete telemetering unit in its pressurized container. Pressurization is, of course, necessary to avoid arc-over and corona at the lower pressures which the missle

passes through. The system uses subminiature tubes, operates at a frequency of approximately 1,000 mc., and has a peak power output between 1 and 2 kw. The entire record of a flight is recorded on the ground by several different methods, the most important of which is a string oscillograph. A picture of a typical recording is shown in figure 2.

We have under development and should have in use within the next 6 months a 30-channel telemetering system using a 300-cycle sampling rate (12). By means of a subcommutator we will be able to extend the number of channels to 450 using a sampling rate of approximately 1 per second.

The recovery of data by telemetering is not completely satisfactory in all cases. For example, the telemetering of spectrographic data, although possible, is not very satisfactory. Furthermore, in all cases when the missile begins to gyrate severely, as it does occasionally, the telemetered data is not continuous because the antenna is at times completely shadowed by the missile. For these reasons other methods of data recovery are being studied. One of these methods is the use of drag mechanisms, including parachutes.

The use of drag mechanisms for recovery is probably feasible, but considerable development work still needs to be done. The present method of recovery involves breaking up the missile during its downward flight in such a way that each individual piece coming down has a high drag coefficient and very poor stability, the result being that the piece in question will tumble or float down. It has been found by this method that equipment even after very high flights will arrive at the earth in fair condition, and occasionally will be found completely intact. Thus, for example, on our October 10 flight, the spectrograph which was installed in a tail fin was recovered in such a good condition that further calibration runs were made on it in the laboratory without readjustment. The induced break-up had torn the fin loose and it had apparently floated back to the earth. Eight pounds of TNT tied to the beams supporting the warhead are usually used to produce blow-off. The correct time of detonation is obtained by means of a timer mechanism and also by means of radio such that the TNT is detonated by the appropriate one of these two methods at an altitude of about 60 km. above the earth on the downward flight. A photograph of a V-2 after a 170-km. high flight is shown in plate 2, figure 1. By this means we have to date recovered 4 spectrographs (2 in usable condition), 3 photographic recorders, 4 still-picture cameras and 10 motion-picture cameras, most of which went to an altitude of 170 km. In all cases the films were in excellent condition, even though in some cases no precautions were taken to protect them on impact.

Our present program is concerned with four fields of high-altitude research, namely, cosmic rays; the ionosphere; pressure, temperature, and composition measurements; and astrophysics involving primarily the spectrum of the sun. A typical lay-out of these various experiments in a V-2 is shown in the sketch, plate 2, figure 2. A more detailed view of the installations in the warhead and control chamber is shown in plate 3, figures 1 and 2, and plate 4, figure 1. Beginning at the extreme nose tip of the missile we have an installation for measuring ram pressures. Immediately behind this in the warhead is the cosmic-ray telescope with the necessary electronics below the telescope. The ionosphere transmitter is directly below the cosmic-ray electronics. Also in the warhead are a timer, remote-control switching panel, accelerometers, telemetering commutator, batteries, and miscellaneous equipment. In the control chamber immediately behind the warhead are the telemetering transmitter, several

distribution and testing panels, and the TNT for blowing off the warhead. In the midsection between the alcohol and oxygen tanks, two cameras are mounted for taking pictures at intervals on the way up. The cosmic-ray film-recording camera is mounted on one of the motor supports immediately below the oxygen tank. The spectrograph is mounted in one of the fins and is provided with a fairing to maintain the necessary streamlining of the fin. At the extreme tail end of the missile are mounted the various antennas for telemetering, ionosphere, and emergency cut-off equipment. I should now like to discuss each of the various experiments at greater length.

Cosmic Rays

There are many cosmic-ray experiments that one can perform even in a rocket which spends only 4 or 5 minutes above the atmosphere. Of all the possibilities we felt that two stood out above all others, namely: 1, a determination of the nature of the primary radiation (heretofore the nature of the primaries could be inferred only from studies of the secondary or tertiary radiation within the atmosphere), and 2, a study of the fundamental reactions taking place as the primaries pass through the atmosphere.

Until the advent of the rocket, cosmic-ray experiments had been conducted in balloons up to an altitude of about 24 km., corresponding to an atmospheric pressure of 2 cm. of mercury. These experiments (13, 14) had determined the distribution of the total as well as the "hard" cosmic radiation through the atmosphere, and they indicated that even at pressures as low as 2 cm. of mercury the primary radiation had already reacted with air nuclei to produce a secondary radiation generally considered to be mesons. The V–2 was capable of reaching the region of the primaries (up to this time generally considered to be protons by most workers in the field (14, 15) and also of passing through the very interesting region in which the ultranucleonic transformations, which result in meson production, take place. One of the latter was assumed to be the very important and fundamental proton-meson reaction about which very little is known, since it apparently occurs on earth only in the cosmic radiation at the top of the atmosphere.

Four different cosmic-ray experiments have been successfully performed to date in four different flights (16, 17, 18, 20, 21). At the present time three more experiments are in preparation for incorporation in flights during May and July 1947. The results of these experiments have given more insight into the nature of the cosmic radiation. The first two experiments established the fact that the greater portion of the primary radiation consists of "hard" particles (i. e., particles which will penetrate at least 12–15 cm. of lead) and that about one out of every five such particles will produce a shower in 12 cm. of lead. In addition it was found that large showers were produced by the primaries in the rather considerable mass of material in the warhead which surrounded the counter telescope. On the basis of this information the third and fourth experiments were performed, which I should like to discuss in greater detail.

The third experiment (18) consisted of two parts. In the first part a cosmic-ray telescope was arranged to test the penetrating properties of the incoming ionizing radiation. It was found that (at a zenith angle of 45°) about 60 percent of the radiation was absorbable in a large thickness of lead (14 cm.). The other properties of the high-altitude radiation were again verified, i. e., the large numbers of warhead showers, and the showers under 14 cm. of lead (28 percent in this measurement). The second part of the experiment, conducted in the same flight, tested for penetration

through two successive lead plates each only 2 cm. thick. It was then found that about 35 percent of the high-altitude rays were stopped in either the first plate or penetrated it and stopped in the second. This indicated that at least this component was not primary (if the improbable case is excluded that it consisted of nuclei of high atomic number). It has been suggested (19) that these are electrons which arise from the atmosphere below and are due to meson decay. The ones observed presumably originated above South America and spiraled around the earth's magnetic field lines to reach the point of observation. The remainder of the radiation (i. e., 65 percent) was observed to penetrate the 4 cm. of lead, some of it producing showers in either the first plate, the second plate, or both. An upper limit to the relative number of primary electrons is obtainable from these data. First, it cannot be greater than 65 percent minus 40 percent or 25 percent of the total radiation (including the nonprimary electrons). Second, it must be less than the relative number of events in which showers were produced below 2 and 4 cm., since some of these are ascribed to particles of high penetrating power. This reduces the possible number of primary electrons to 9 percent of the total or 18 percent of the primary radiation.

The fourth experiment (20) consisted of a counter tube telescope arranged so that the percentage of particles penetrating 2 cm., 6 cm., and 12 cm. of lead could be determined. The number of threefold showers under these same thicknesses was also measured. The telescope was mounted vertically in a specially designed warhead so that it looked directly through the warhead nose as shown in figure 3, and in plate 3, figure 1, and plate 4, figure 2. The heavy lead shielding around the lower half of the telescope was introduced in an attempt to reduce the number of rocket showers found in previous experiments. This shielding, in conjunction with the absorbing lead plates, was sufficient to eliminate most of the registered rocket showers of primary or nonprimary electronic origin. It was found that the number of rocket showers actually doubled over that of previous unshielded experiments. This would indicate that these showers must be of nonelectronic origin. It was found that, above the atmosphere, 25 percent of the total radiation present was absorbed in 6 cm. of lead. Although this is somewhat less than that found in the first experiment, it is assumed to be the same type of nonprimary electron component discussed above. The different percentages in the two experiments are attributed to the variation of this component with zenith angle. A total of 59 percent of the particles penetrated 12 cm. of lead. The remaining 16 percent was absorbed in 12 cm. In all cases the large portion did not produce showers under the lead. Thus, primary electrons would be ruled out since these would produce large showers under 2 and 4 cm. As a matter of fact it is difficult to understand how any of this component could be due to primary particles since the large energies associated with the primaries should produce some type of reaction below 12 cm. of lead unless, of course, neutral particles are involved. If we assume that all the radiation except that absorbed in 6 cm. is primary, then we find that the electron component determined on the basis of shower production could not be more that a maximum of 14 percent of the primary; the nonelectronic component absorbed in 12 cm. is 18 percent of the primary and the nonelectronic component penetrating 12 cm. is 68 percent of the primary. The ratio of the total radiation in free space to that at sea level was 11.5. The ratio of the hard component (that which penetrated 6 cm. of lead) in free space to that at sea level was 9.0.

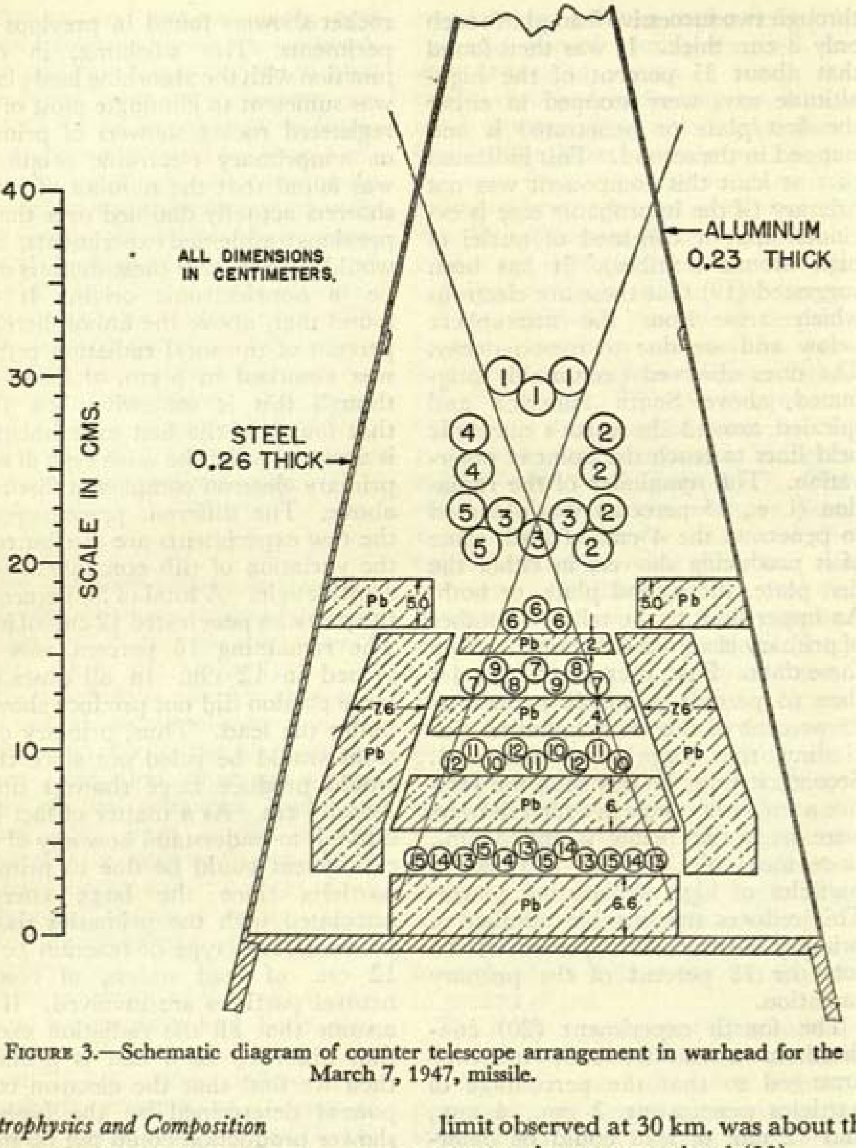


FIGURE 3.—Schematic diagram of counter telescope arrangement in warhead for the March 7, 1947, missile.

Astrophysics and Composition

Because the earth's atmosphere had limited spectroscopic observations of the sun to a lower wave-length limit of 2863 A. (22), astronomers have long been looking forward to the time when the unknown far-ultraviolet region could be observed. Even though balloons could reach altitudes of 30 km. they were not quite able to pierce the ozone layer and, because of the ozone absorption band which lies just below 2900 A., the lower wave-length limit observed at 30 km. was about the same as it was at sea level (23).

A rocket which reached altitudes of 170 km. and higher should prove very valuable in further solar spectral studies. To get such a spectrum and at the same time to get more constructive information on composition of the atmosphere, a special vacuum grating spectrograph, shown in figure 4, was designed to fit into the V–2 (6). Two small lithium fluoride beads are used for obtaining a wide angle of view so

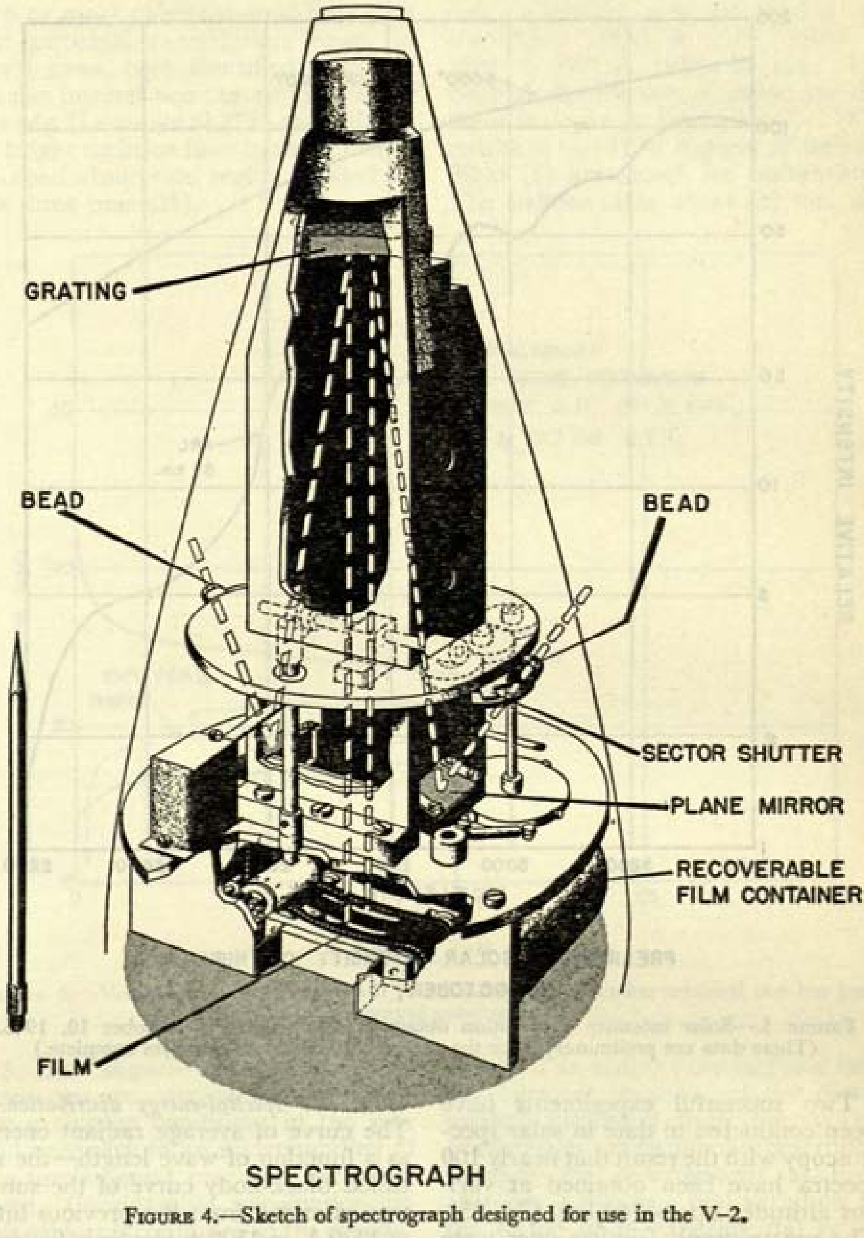
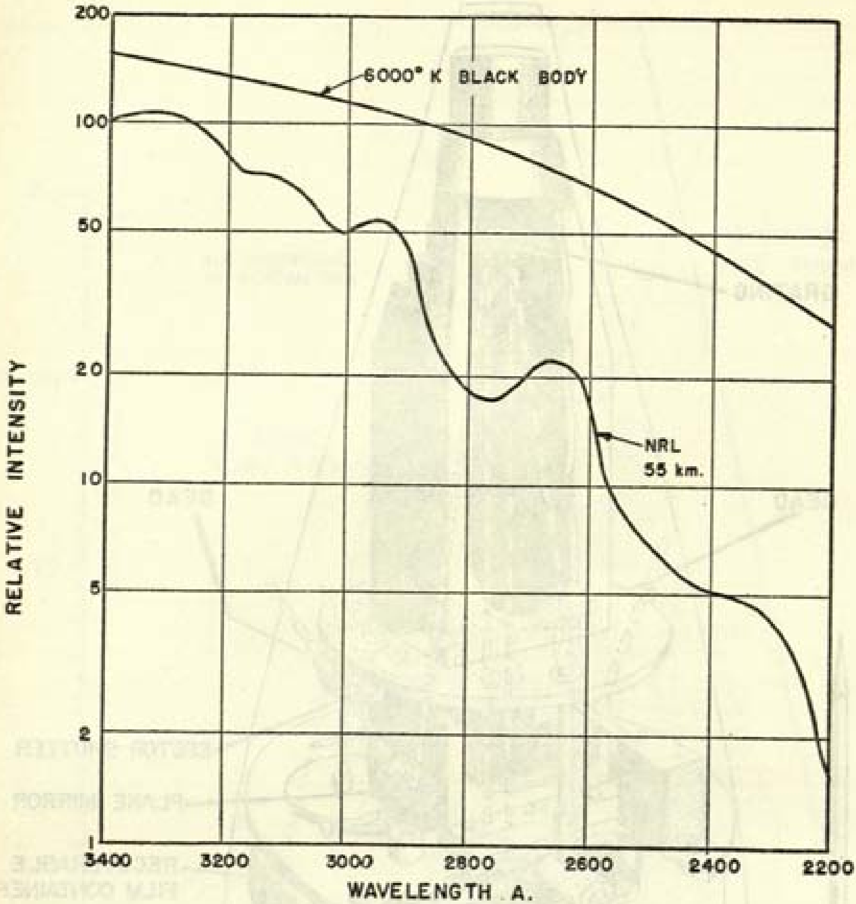


FIGURE 4.—Sketch of spectrograph designed for use in the V-2.

as to minimize the effect of roll and other movements of the missile. The image from this little bead is reflected to a grating and in turn to a 35-mm. film on which the images from the two beads are recorded separately. The spectrograph was originally designed to fit in the nose of the warhead but, because of greater ease of recovery, it has been, in more recent flights, mounted in one of the tail fins. As pointed out previously, spectrographs have on several occasions been recovered in such good condition that they were capable of being used again (24).



PRELIMINARY SOLAR INTENSITY DISTRIBUTION
10 OCTOBER, 1946

FIGURE 5.—Solar intensity distribution obtained from spectra of October 10, 1946. (These data are preliminary since the analysis of all spectra is not yet complete.)

Two successful experiments have been conducted to date in solar spectroscopy with the result that nearly 100 spectra have been obtained at various altitudes up to 160 km. (24, 25). The spectrograph (similar ones were used in the two flights) was arranged to record only the wave lengths below 3400 A.; in some of the spectra obtained at higher altitudes radiation was recorded down to 2100 A. Analysis of these spectra has produced the following results.

1. *Solar spectral-energy distribution.*—The curve of average radiant energy as a function of wave length—the so-called black-body curve of the sun—was extended from the previous limit of 2900 A. to 2200 A. shown in figure 5. The ultraviolet intensities are much less than had been predicted (26).

2. *Fraunhofer line analysis.*—A large number of fully and partly resolved absorption minima were observed in the region between 2950 and 2300 A., as shown in plate 5, figure 1. Nearly

all observed minima are blends from two or more closely spaced lines, but the principal contributors have, in many cases, been identified. Of particular interest was the appearance of the Mg II doublet at 2795 and 2802 A. as bright emission lines in the center of a broad absorption region created by the same pair (25).

The effect of the absorption of ozone can be clearly seen by noting the absorption band in the region of 2300 to 2800 A. below 55 km. The vertical distribution of ozone on this flight is shown in figure 6 (27). The results of the 1936 *Explorer II* balloon flight (5) are shown for comparison. The balloon data above 22 km. are

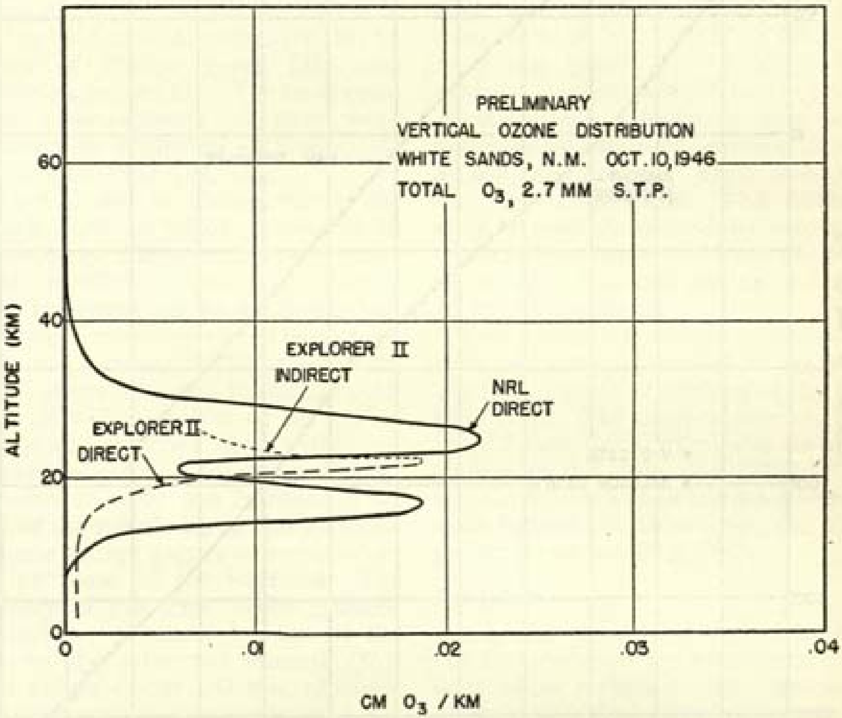


Figure 6.—Vertical ozone distribution. The double layer is rather unusual but has been reported previously.

3. *Line shapes*.—Line widths and intensities are important in determining excitation conditions in the sun, and necessary to an understanding of the fundamental processes occurring there. Considerable information on this subject is contained in the spectra. Full analysis and evaluation of conditions in the sun will require another year or more of intensive work.

4. *Ozone*.—The variations of the spectra with altitude for the October 10 flight are shown in plate 5, figure 2.

based on an indirect method and lack the inherent accuracy of the direct method employed from the rocket. Further data are required to determine whether the disagreement at high altitudes is due to a real variation in the ozone or to experimental error. The lower maximum is known to be present on days when the total ozone content of the atmosphere is abnormally high (28).

5. *Sky brightness*.—Some data in the ultraviolet are available. The experi-

ments were not, however, designed particularly for this problem.

Future experiments in this field will aim at still lower wave lengths and greater resolution.

Although we have a vehicle which will carry us to an undreamed-of altitude, the problem of measuring such basic quantities as pressure and temperature from a missile which is

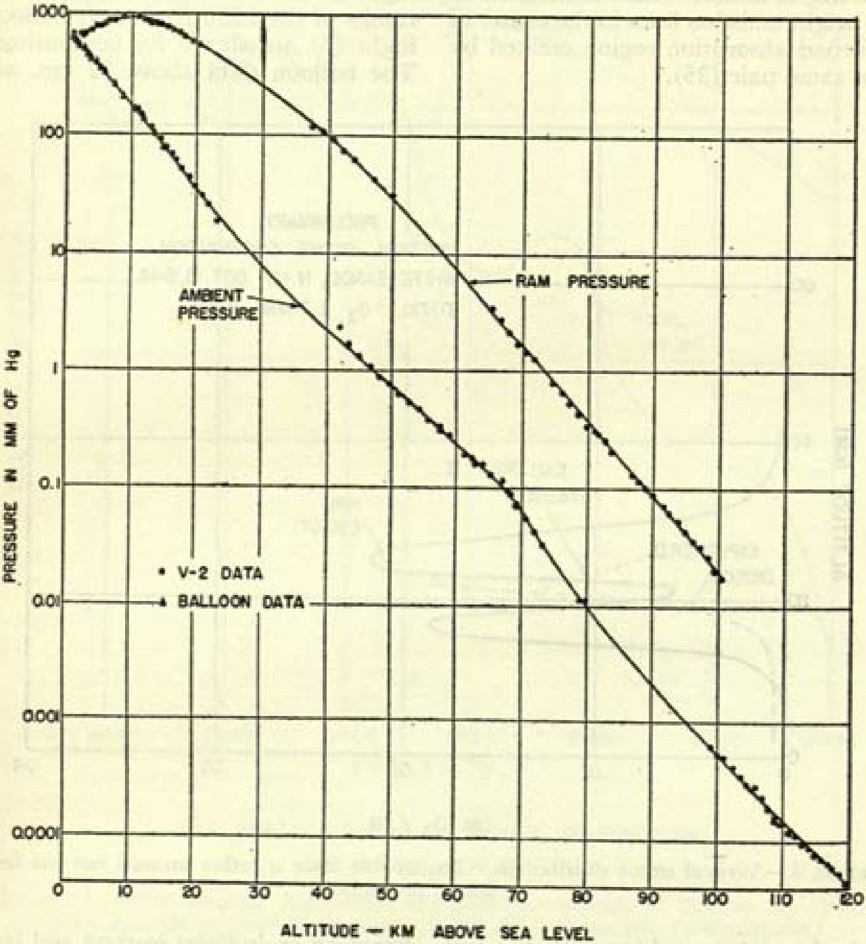


FIGURE 7.—Variation of pressure with altitude.

Pressure and Temperature Experiments

Actual measurements of pressure and temperature in the upper atmosphere have been made for many years by various methods. Balloons regularly obtain this information up to 30 km. Above this altitude various indirect methods have been used, including measurements on meteors (29), sound-range measurements of large explosions (30), and others (2).

moving at a velocity of 1 mile a second is far from easy. This becomes clear when one calculates the adiabatic temperature rise on a thin piece of material placed on the nose of the V-2. For the velocities involved this temperature is higher than 1000° C.

Our attack on the problem to date has been to measure the so-called ram pressure at the nose of the missile and the pressure at a point on the side of the missile at which, according to

wind-tunnel tests, the pressure is within a very small percentage of ambient. Since a pressure range of 10^8 is covered in a normal flight, it is necessary to use various types of gages. The range from atmospheric pressure down to about 1 cm. of mercury is covered with a bellows gage; the range of 2 cm. mercury to 10^{-3} mm. mercury is measured with Pirani gages (31) while the region of 10^{-3} to 10^{-6} mm. mercury is studied by means of Philips gages (32) and ionization gages (33). The most complete measurements to date were obtained on flights in October 1946 and March 1947 (34, 35).

I would like to discuss briefly the March flight in which a total of 15 pressure and 2 skin-temperature gages were installed. Ambient pressures were measured up to about 80 km. with gages mounted on the side of the V-2, just forward of the tail section. Pirani gages mounted in similar positions on opposite sides of the rocket gave readings which agree within experimental errors, indicating that no appreciable error was introduced by yaw of the missile up to this altitude. A single Philips gage was mounted on the 15° cone of the warhead. The readings of this gage, when reduced to ambient pressures by use of the theories of Taylor and Maccoll (36), gave values up to 120 km. altitude. Pressure measurements obtained by these two methods are shown in figure 7.

Temperature measurements are of two types: 1, measurement of ambient temperatures; and 2, measurement of skin temperatures and temperatures within the missile. The direct measurement of ambient temperatures from a rocket has not yet been successfully accomplished. The temperature of the atmosphere was calculated from the slope of the pressure vs. altitude curve and from the ratio of ram to ambient pressures. Pitot tube theory was used to obtain Mach number from the ratio of ram pressure to ambient pressure. The velocity of the rocket divided by Mach number gave the velocity of sound, from which temperature was calculated. Figure 8 is a plot of the temperatures derived by these methods. Shown also are the temperatures measured by means of a weather balloon released within an hour of the time of the rocket's flight. For comparison, the NACA estimated mean temperature (37) is included on the curve. Probable error is ±25° from 50 to 60 km., ±15° at 65 to 70 km., and ±20° at 72.5 km. The probable error above 100 km. is ±40°. Temperatures calculated from ram pressures for altitudes between 10 and 20 km. are 5 to 20° lower than the expected temperature. This discrepancy is possibly caused by errors in the velocities calculated from the poor radar data obtained during the first 20 km. of the flight.

Two platinum resistance temperature gages were installed to measure the temperature of sections of the 15° nose cone. The temperature rise on the 0.1-inch-thick aluminum forward section of the nose was 120±5° C. On the 0.1-inch steel section immediately behind the aluminum, the temperature rise was 85±5° C.

Ionosphere

It is now possible to extend further our knowledge of the ionosphere (38) by utilizing rockets to make measurements within the ionized region of the upper atmosphere.

The value of experimental methods utilizing rockets may be shown by a consideration of the parameters involved in the simple approximate expression for the index of refraction in an ionized medium, neglecting the earth's magnetic field.

$$n=\sqrt{1-\frac{4\pi N_e^2}{w^2 m}} \tag{1}$$

n: Index of refraction.
N: Ion density.
e: Charge on the ion.
m: Mass of ion.
w: Angular frequency of radiation.

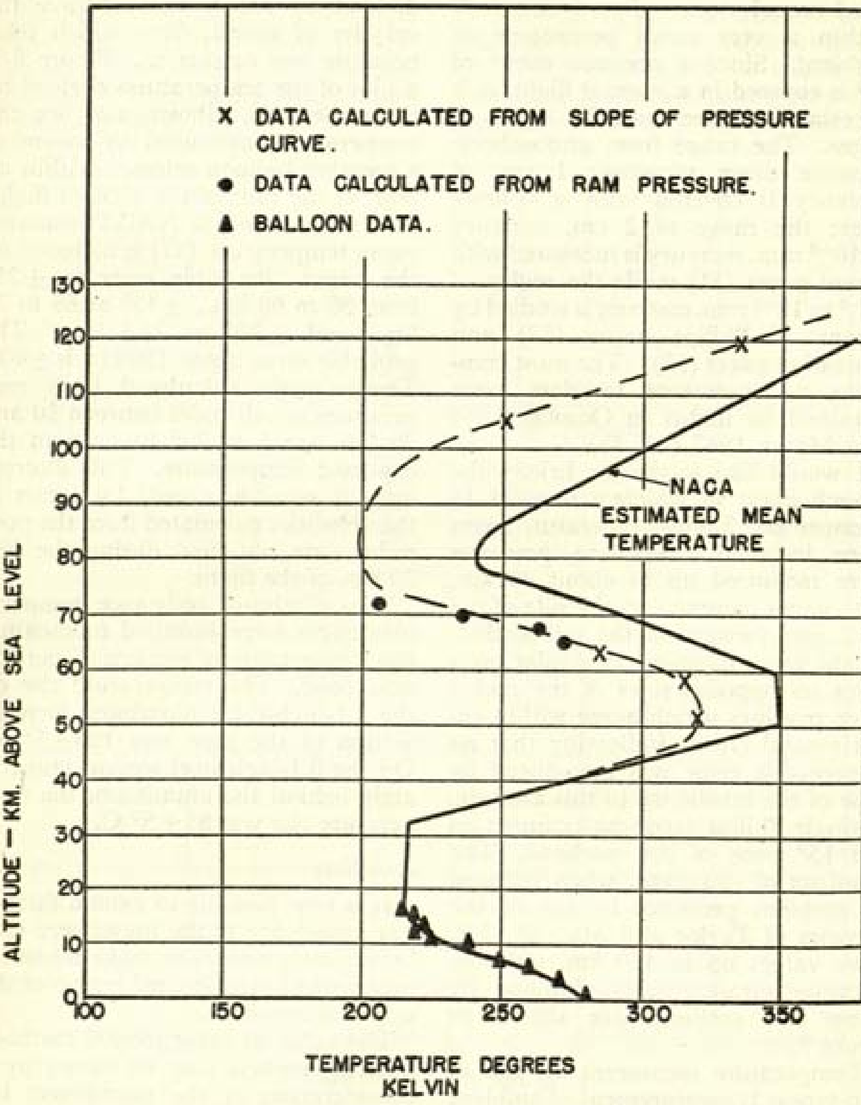


Figure 8.—Variation of temperature with altitude.

Radio pulse ionosphere height-finding methods in wide use today (39) can at most measure directly the index of refraction at certain points, whereas rocket-borne experiments may be designed to measure directly both the index of refraction and the ion density *N* at all points reached by the rocket. The V-2 reaches altitudes corresponding to the top of the *E* layer. Since in the *E* layer there is at present ambiguity as to the ratio of free electrons to ions, rocket-borne experiments are the most direct way to determine whether the parameter on the right-hand side of the expression should be in terms of electrons, ions, or both. A determination of data such as these will permit more accurate knowledge of many of the factors affecting long-distance radio propagation, such as delay times, velocities of propagation,

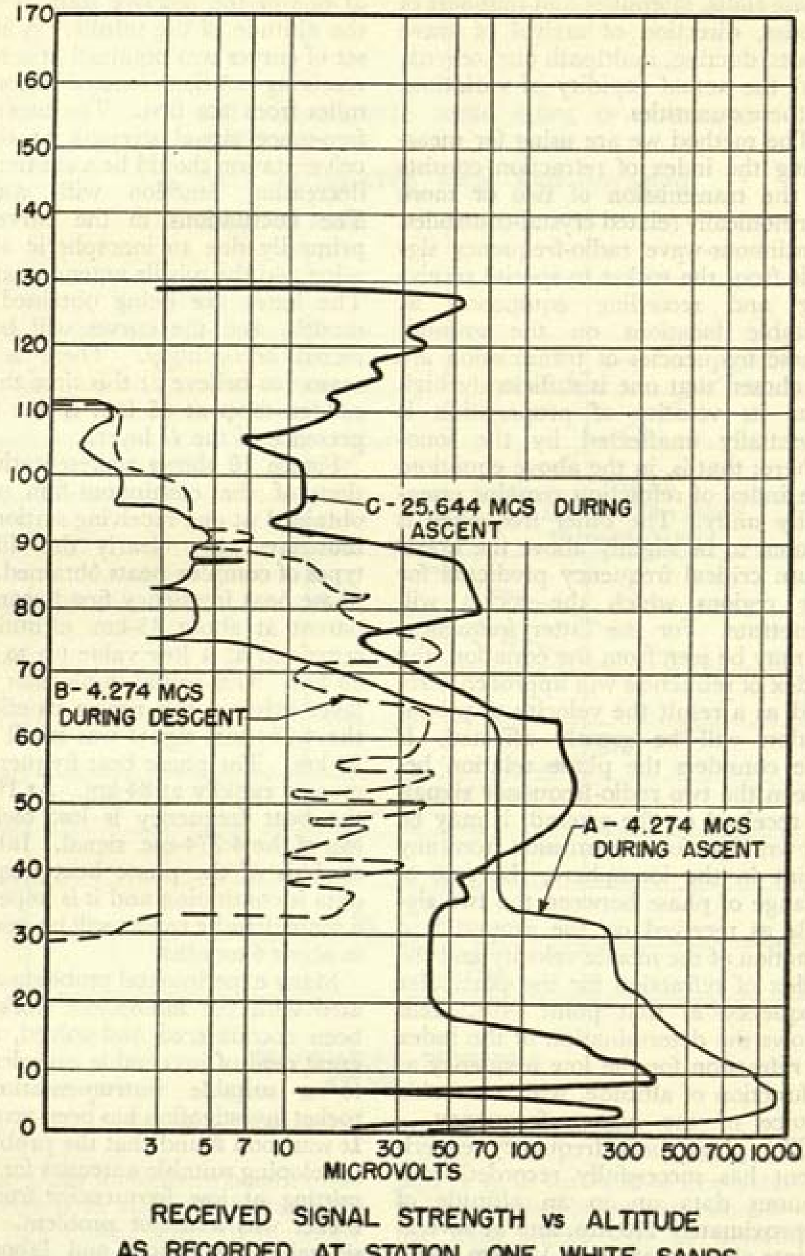
phase shifts, intensities and numbers of modes, direction of arrival of wave fronts, ducting, multipath phenomena, and the actual rapidity of variations of these quantities.

The method we are using for measuring the index of refraction consists of the transmission of two or more harmonically related crystal-controlled continuous-wave radio-frequency signals from the rocket to special receiving and recording equipment at suitable locations on the ground. These frequencies of transmission are so chosen that one is sufficiently high that its velocity of propagation is essentially unaffected by the ionosphere; that is, in the above equation, the index of refraction remains essentially unity. The other frequency is chosen to be slightly above the maximum critical frequency predicted for the regions which the rocket will penetrate. For the latter frequency, as may be seen from the equation, the index of refraction will approach zero, and as a result the velocity of propagation will be greatly affected. If one considers the phase relation between the two radio-frequency signals as received on the ground, it may be shown that for transmission from any point in the ionosphere, the rate of change of phase between the two signals as received on the ground is a function of the missile velocity and the index of refraction for the particular frequency at that point (40). This allows the determination of the index of refraction for the low frequency as a function of altitude, with a suitable choice of the higher frequency.

The phase beat frequency experiment has successfully recorded continuous data up to an altitude of approximately 110 km. and at several points above that up to 128 km. (41). Although the analysis of these data is very complex and although only a preliminary analysis has been made, I would like to point out a few of the interesting results of this experiment. Figure 9 shows a series of curves of the received signal strength on the ground at one of the receiver stations versus the altitude of the missile. A similar set of curves was obtained at a second receiving station located about 30 miles from the first. The theoretical free-space signal strength at the receiver station should be a continuously decreasing function with altitude. The fluctuations in the curves are primarily due to ionospheric attenuation and the missile antenna patterns. The latter are being obtained from models, and the curves will be corrected accordingly. There is some reason to believe at this time that the sudden drop at 65 km. is due to the presence of the *D* layer.

Figure 10 shows representative sections of the continuous-film records obtained at one receiving station, and illustrates very clearly the different types of complex beats obtained. The phase beat frequency first became apparent at about 43-km. altitude and remained at a low value up to about 84 km. This would imply that if a *D* layer exists in this region its effect on the 4.274-mc. signal was small below 84 km. The phase beat frequency increased rapidly at 84 km. At 111 km. the beat frequency is lost owing to loss of the 4.274-mc. signal. Intensive analysis of the phase beat frequency data is continuing and it is hoped that a more definite report will be available in about 6 months.

Many experimental problems associated with the ionosphere work have been encountered and solved, and a great deal of invaluable experience as to a suitable instrumentation for rocket investigation has been acquired. It was soon found that the problem of developing suitable antennas for transmitting at low frequencies from the rocket was a major problem. Considerable theoretical and laboratory research has been carried out to establish a fundamental basis for the direct measurement of the electron and ion densities as a function of altitude. An experiment is virtually complete for inclusion in a July flight, which involves primarily a determin-



RECEIVED SIGNAL STRENGTH vs ALTITUDE AS RECORDED AT STATION ONE, WHITE SANDS, BETWEEN 11:23 AND 11:30 A.M. M.S.T. ON MARCH 7, 1947

FIGURE 9.

ation of the saturation current for electrons and positive ions.

Miscellaneous

Cameras have been included in several flights and pictures obtained to altitudes of 160 km. (42). A composite of several such pictures is shown in plate 6. The Gulf of California and surrounding territory are clearly evident in the picture. Photographs of this type are very useful for meteorological cloud studies as well as for cartographic purposes.

On the night of December 17, 1946, the first night V-2 launching in this country was made for the purpose of conducting an experiment with artificial meteorites. This experiment, conducted jointly by the Applied Physics Laboratory, the California Institute of Technology, and Harvard University, consisted of dropping out special charges, at intervals of about 20,000 feet, above 60,000 feet. The charges were to explode 1 or 2 seconds after leaving the missile. High-velocity particles should then appear as artificial meteors and as a matter of fact in a few cases some of the particles might have enough velocity to escape the earth. This experiment was unsuccessful because of ejection difficulties but will be repeated sometime this fall.

On various flights special strains of rye seeds, corn seeds, and fruit flies have been taken to altitudes of 170 km. to determine whether radiation above the atmosphere might produce mutations. The order of magnitude of cosmic radiation was, of course, known and because of its low intensity very little or no effect was anticipated. However other less energetic radiation might exist at these altitudes which could possibly produce an effect. Analysis made by Harvard on recovered seeds and flies has shown that no detectable changes are produced by the radiation. These results are not yet conclusive because in most cases the seeds were shielded by metal (in order to facilitate recovery) so that only the higher energy radiation would have been effective. If recovery methods are improved, containers having very thin walls will be used to study the effects of the lower energy radiation.

In general the various laboratories involved are approaching the above problems in different ways. Numerous other experiments are being planned for the future, of which a few might be mentioned. The Applied Physics Laboratory and the Watson Laboratories are both planning differ-

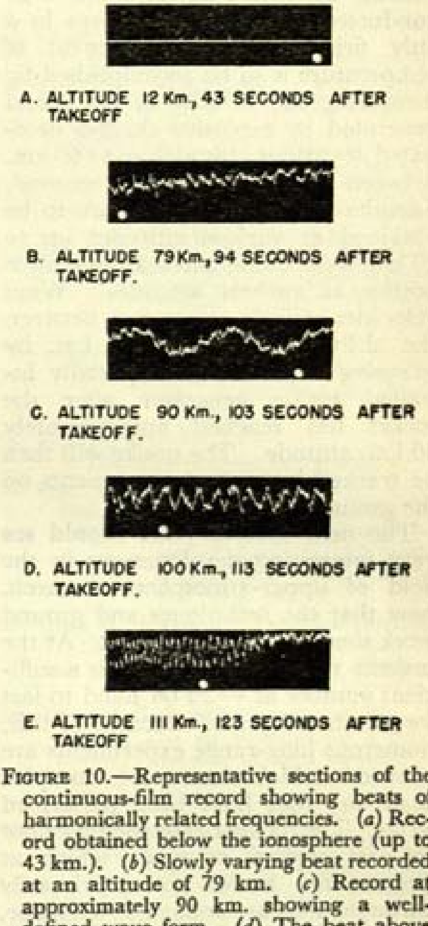


FIGURE 10.—Representative sections of the continuous-film record showing beats of harmonically related frequencies. (*a*) Record obtained below the ionosphere (up to 43 km.). (*b*) Slowly varying beat recorded at an altitude of 79 km. (*c*) Record at approximately 90 km. showing a well-defined wave form. (*d*) The beat above 100 km. showing a more complex wave form. (*e*) The sudden cessation of the phase beat frequency at 111 km. at which point the 4.274 mc. signal disappeared completely.

ent types of experiments to measure the intensity of the earth's magnetic field at different points in space. Three very interesting experiments—one to measure temperature, a second to take samples of the atmosphere, and a third to measure wind direction and velocity at various altitudes are to be conducted by the Signal Corps in a July firing. The measurement of temperature is to be accomplished by measuring the velocity of the sound generated by explosive charges detonated at various altitudes up to 60 km. between the rocket and the ground. Samples of the atmosphere are to be obtained at various altitudes up to 80 km. by opening and sealing sample bottles at various altitudes. Wind velocities will be measured between the altitudes of 30 and 60 km. by releasing smoke from a specially installed smoke generator after the rocket has reached approximately 30 km. altitude. The smoke will then be tracked by optical instruments on the ground.

The next several years should see very interesting developments in the field of upper-atmosphere research, now that the techniques and ground work therefor have been laid. At the present rate of firings there is a sufficient number of V-2's on hand to last for another 2 years. Because of this, numerous long-range experiments are planned which are more complex than any that have been performed so far. The rocket has opened the door to vast regions of space which at present are known to us primarily through the astronomer's telescope. When one considers the large amount of work that has been done by the astronomers and the greater understanding of the universe that this work has given us, one cannot help being impressed by the research potentialities of this new field.

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Roentgen Rays Against Cancer[1]

By JOHN G. TRUMP, *Associate Professor of Electrical Engineering, Massachusetts Institute of Technology*

[With 6 plates]

The disease to which Hippocrates in the fourth century B. C. applied the enigmatic and disquieting name of "cancer" is now for the first time marked for open battle by the combined forces of science, medicine, and enlightened public opinion. Cancer has made a vivid and fearful impression upon the human mind since antiquity. The earliest account of some of its clinical symptoms is recorded in an Egyptian papyrus of the fifteenth century B. C. Many observations of its nature had been made by the end of the Hippocratian era, and further accurate classification of the disease was accomplished in A. D. 150 by Galen, whose principles persisted until the nineteenth century. Today the ultimate nature and causes of cancer are still largely a riddle, but knowledge of its almost infinite manifestations and factors affecting them is steadily advancing. While cancer the disease is growing in social importance, the successes in cancer research and therapy have been many and can now occasionally offer hope of complete clinical cure. In this battle against the most mysterious and baffling of human diseases, the armamentarium of humanity includes the techniques of the physicist, chemist, geneticist, biologist, bacteriologist, as well as the internist, surgeon, and radiologist. Most recently, because of the critical need for early diagnosis and enlightened response, the general public is being awakened to its necessary role in this developing conflict.

Among the civilized countries of the world, cancer is now definitely second only to the diseases of the heart as a cause of death. In the United States about 175,000 people die annually of this disease. More than 1 in 10, about equally divided between men and women, are destined to die of cancer. The apparent rise through the years in the incidence of this disease is undoubtedly due to improved diagnosis and to the increasing age of populations, for cancer preferentially strikes those of middle and advanced age, although certain types, such as embryonal tumors, are more common in early life. Several hundred varieties of malignant tumors are now recognized, and their characteristic development has been the subject of clinical observation for many years. More important, fundamental processes in the origin of cancer and its control are the subject of intensive research. The genetic factor in the incidence of cancer has been studied in both men and animals, as well as the carcinogenic effect of mechanical irritation, of certain chemical compounds, of bacteria, of viruses, and of exposure to radiation. The study of transplantable tumors and the factors contributing to the development of the graft or the maintenance of immunity, the

[1] Reprinted by permission from The Technology Review, vol. 50, No. 2, December 1947, edited at the Massachusetts Institute of Technology.

possibilities of ionizing radiation to inhibit the growth of, or to destroy, malignant tissue, the use of hormone and certain chemical inhibitors, and a host of other types of fundamental biologic, physical, and clinical research are throwing light on the basic problem of cancer.

Two Accepted Forms of Cancer Therapy

Even with this long background of intensive investigation, the only two accepted methods of treatment for cancer are surgery and radiation therapy. With few scattered exceptions, it is only by completely exorcising the malignant tumor or by removing it in situ with cell-destroying radiations that this disease can now be controlled or eliminated. Both these techniques, often used in combination, have resulted in thousands of clinical cures, particularly in the case of superficial malignancies or in deep tumors detected in their early stages. Both these techniques have improved steadily with time. The former has progressed because of the increasing skill of the surgeon and the anesthetist and their techniques now permit the removal of new growths from nearly any organ or tissue of the body. The latter has depended upon the development of new and more effective forms of radiation intelligently employed by the radiologist. Cancer of the lip, mouth, larynx, uterus, and bladder is often treated by radiation alone. In addition, radiation plays an indispensable role in combination with surgery for the control of many other types of malignant tumors. It is in the field of radiation therapy that significant contributions have been made by the research groups at the Massachusetts Institute of Technology, where engineering, physical, and clinical research on cancer has been in progress for more than a decade.

Supervoltage Roentgen-Ray Treatment

The problem of the radiologist is to deliver to the malignant tumor such a quantity of ionizing radiation as to effect its gradual, but complete, destruction while causing only a tolerable injury to surrounding healthy tissue. Particularly in the treatment of deep tumors and those concerned with vital organs has the use of penetrating and ionizing radiation been indispensable. Within a few months of Roentgen's discovery the therapeutic, as well as the diagnostic, value of X-rays had been noted, and X-rays were being employed for the treatment of superficial lesions. A few years later, Madame Curie's brilliant isolation of radium, whose products emit a similar but far more penetrating radiation, added another powerful tool for therapy. During the next 50 years the relatively low-voltage and easily absorbed roentgen rays available to Roentgen's medical confreres have been gradually increased to about 250-kilovolt radiation for the deep-therapy application. The limited amount of radium is used to an increasing extent only in direct application to accessible tumors—those on the surface or accessible through the body orifices. In interstitial therapy the gamma-ray emitting needles or seeds are inserted into the tumor mass. Deep tumors, the most serious clinical problem, are now universally irradiated with roentgen rays in the 250-kilovolt energy range, assisted in certain cases by gamma-ray irradiation.

That higher voltages would produce a superior quality of radiation for deep therapy has been appreciated for many years. During the last decade, however, less than a dozen clinical institutions in the world have had available X-ray sources operating in the vicinity of 1 million volts. Dr. Robert S. Stone of the University Hospital in San Francisco has treated patients since 1935 with million-volt radiation produced by the ingenious high-frequency Sloan generator now obsolete because of its complexity. In 1937 Dr. Richard Dresser of Harvard's Huntington Memorial Hos-

pital in Boston began the first constant-potential X-ray treatments with the M. I. T. air-insulated electrostatic generator operating at slightly more than 1 million volts. This was followed by the Massachusetts General Hospital program in 1940, under Dr. George W. Holmes and now Dr. Laurence L. Robbins, using M. I. T.'s 1¼-million-volt pressure-insulated generator. At the St. Bartholomew's Hospital in London clinical treatments were begun by Dr. Ralph Phillips in 1937 at 700 kilovolts and the large transformer-rectifier apparatus was gradually improved to million-volt operation. The Memorial Hospital in New York has used General Electric's million-volt resonance transformer for X-ray therapy for about 10 years. In Norway, Dr. S. N. Bakke of the Municipal Hospital, Haukeland, Bergen, began treatments in 1942 with a 1¼-million-volt air-insulated electrostatic generator designed by Odd Dahl, formerly of the Carnegie Institution of Washington. A number of other programs at intermediate voltages could be mentioned. All have reported with varying degrees of enthusiasm the observation that certain more favorable therapeutic reactions could definitely be ascribed to the higher voltages at which the X-rays were generated.

Radiation Therapy at 2 and 3 Million Volts

Since January 1946, in a clinical therapy program under the medical direction of Dr. Richard Dresser, patients have been treated on the grounds of M. I. T. with roentgen radiation produced by an electrostatic research generator which can operate at well over 3 million volts. In the ensuing 18 months, complete treatment series were given to more than 150 selected patients. After interruption during the summer of 1947 this clinical program will be resumed with a larger clinic and improved, higher-voltage apparatus. Roentgen radiation produced by 3 million volts exceeds in quality the gamma rays from radium in equilibrium with its decay products. The output intensity of this therapeutic generator is several times greater than the combined radiation output of the entire world supply of this precious material. This roentgen-ray source operates at the highest voltages thus far clinically used in cancer therapy. The preliminary observations made in the course of the work have generally confirmed the physical evidence that roentgen rays of several million volts of energy are superior in certain important respects to the relatively low-energy radiation now in common use and even considerably better than the 1-million-volt radiation investigated over the last decade. That extensive clinical research by many investigators will be required to exploit fully the therapeutic qualities of these high-energy radiations is also evident; several years of physical and clinical research will be needed to consolidate the benefits derived from higher voltages.

The supervoltage X-ray source located in a small building on Institute property near Vassar Street in Cambridge is a pressure-insulated electrostatic generator of the type first developed by Robert J. Van de Graaff. Designed by the electrical engineering group in 1940 for physical and medical research, it was applied during World War II to the irradiation of atomic-pile materials with intense ionizing radiations and also served as a prototype for the electrostatic generators developed at M. I. T. for military radiography. Now, reapplied to peaceful pursuits, high priority is given to the daily medical program, but the unusual quality and quantity of ionizing radiation produced by this equipment is also of interest in other investigations. In a cooperative study with the Department of Food Technology, the biological and photochemical effects of both X-rays and cathode rays on micro-organisms and on food and drug products are being studied. In another aspect of this

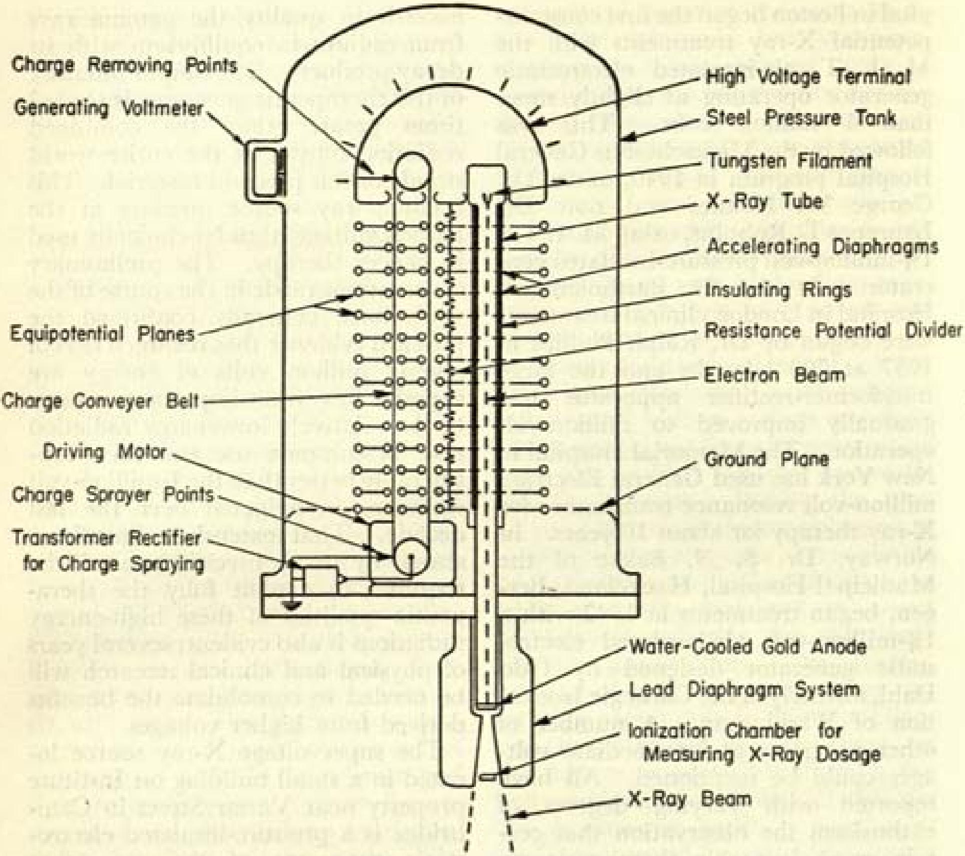


FIGURE 1.—Diagram of an electrostatic X-ray generator. Following the original suggestion of R. J. Van de Graaff, electric charge is transferred to the high-voltage terminal at a continuous rate by a belt of insulating material. This charge maintains the terminal at a steady negative potential with respect to ground, and supplies the electrons required by the acceleration tube. Both tube and belt are mounted within the insulating column which is especially designed to insure a uniform voltage distribution between terminal and the ground plane. Electrons emitted from the hot tungsten filament at the high-potential end of the tube are progressively accelerated and focused as they pass along the acceleration tube and thus acquire the full potential of the terminal. On impact with the water-cooled gold anode, the kinetic energy of the electrons is transferred into penetrating radiant energy. Since this radiation is emitted in all directions, a lead diaphragm system is used to absorb the unwanted radiation and to define the beam of ionizing radiation used in therapy. Except for the interior of the highly evacuated X-ray tube, the entire apparatus is insulated by compressed gas at a pressure of 27 atmospheres. It is this feature which permits these instruments to be built with unusual compactness.

program the physical properties of these radiations and their action on nonliving matter are actively followed.

An important therapeutic property of these supervoltage roentgen rays is the unusually high skin tolerance which almost completely eliminates skin damage in the treatment of deep tumors. In the past, X-ray therapy has suffered from the limitation that the radiation must enter through the relatively radiosensitive skin and undergo very considerable attenuation and misdirection by the absorption and scattering processes before it reaches the site of a deep tumor. Many of these difficulties are reduced by the skill of the radiologist in the

choice of treatment distance, field size, number of portals through which the radiation is directed, and fractionation technique by which he distributes the total dose over a period of days or weeks. More often than not, however, in the present treatment of deep-seated malignancies, the tumor dose is established not by the optimum amount required to destroy the tumor, but rather by the tolerance of the surrounding normal tissue and skin through which the radiation must pass. Most deep tumors treated with 200-kilovolt radiation can be reduced, if at all, only by doses which produce a violent skin reaction and the absorption of sufficient ionizing energy by the patient to produce nausea and other physiological disturbances. In the clinical program at M. I. T. it was found that both of these difficulties have almost entirely disappeared. Doses have been delivered to the site of a deep tumor sufficient to cause its regression with only mild skin erythema or no skin reaction at all. Patients have been treated for abdominal tumors with little or no systemic reaction. Clearly the possibility has been developed for the first time of delivering to a deep tumor a dose defined primarily by the requirements at the tumor site rather than the tolerance of intervening tissue.

A second advantageous property for deep therapy of supervoltage roentgen rays is the substantial increase in penetration of the radiation beam. For a given dose sustained in the region of the skin, 3-million-volt rays will deliver twice as much ionization energy to a tumor at a depth of 10 centimeters as will 200-kilovolt rays. As a result, deep tumors can be much more efficiently irradiated with less damage to surrounding healthy structures and less total ionizing energy absorbed within the body of the patient.

Radiologists have often employed the "cross-firing" technique as a means of delivering a high tumor dose with a minimum of external skin damage. In such procedure the tumor is irradiated from several directions so that the dose is cumulative in the tumor, but distributed in the surrounding healthy tissue and skin. When this technique is likewise applied with supervoltages, unusual selectivity of radiation dose is accomplished. Cross-firing from three directions results in a deep tumor dose which is greater than the highest dose sustained elsewhere in the tissue. Using a continuous cross-firing technique with supervoltage rays, it becomes possible to deliver to a localized deep tumor dosages which are six times higher than those absorbed by even nearby healthy tissue. Thus the dream of the radiologist of delivering to arbitrarily selected regions deep within the body cell-destroying ionization far greater than that sustained in other regions becomes attainable.

Unfortunately the clinical problem is often more complicated. Deep-seated malignancies may not be well defined. Tumors of the bladder, uterus, larynx, and thorax are often localized, whereas other common cancer types are likely to have nearby or distant extensions from the primary tumor site. Metastasis from the primary tumor along the lymph nodes is a common characteristic which requires that these distributed regions of possible malignancy must be found and destroyed. The probable areas where metastasis might occur are often fairly definitely known from clinical experience so that preventive radiation therapy may be initiated even before symptoms appear. It is perhaps even more important to treat effectively the periphery of malignant regions and their actual or anticipated metastases than to concentrate on the primary tumor. Although this clinical problem is more complicated, the use of more penetrating, less scattering, and more skin-favoring supervoltage radiation, combined with real diagnostic and radiologic skill, should pay dividends in increased comfort and life of the patient.

High-voltage Research at M. I. T.

The present medical work with supervoltage X-rays is an outgrowth of a development program for nuclear research which began at M. I. T. in 1932. At that time Robert J. Van de Graaff, then just removed from Princeton where he had developed the electrostatic principle of voltage generation for which he is acclaimed, was constructing the large air-insulated electrostatic generators at Round Hill, New Bedford, for nuclear research. Within the Department of Electrical Engineering investigations were beginning on the insulation of electrostatic generators in high vacuum and on the possibility of developing more compact sources of high constant potentials.

Today the original Round Hill generator, moved to a steel building on the Institute's property in Cambridge, is in continuous use in nuclear studies with electrons or positive ions of 2-million-volts energy. The steady stream of charged particles produced by the electrostatic accelerator is homogeneous and accurately controllable in energy and free from extraneous background radiation. These characteristics are virtually indispensable in certain important precision studies of nuclear structure and are not attained in the cyclotron, betatron, synchrotron, or other indirect particle-accelerators which are inherently capable of producing far greater energies. A new compressed-gas insulated

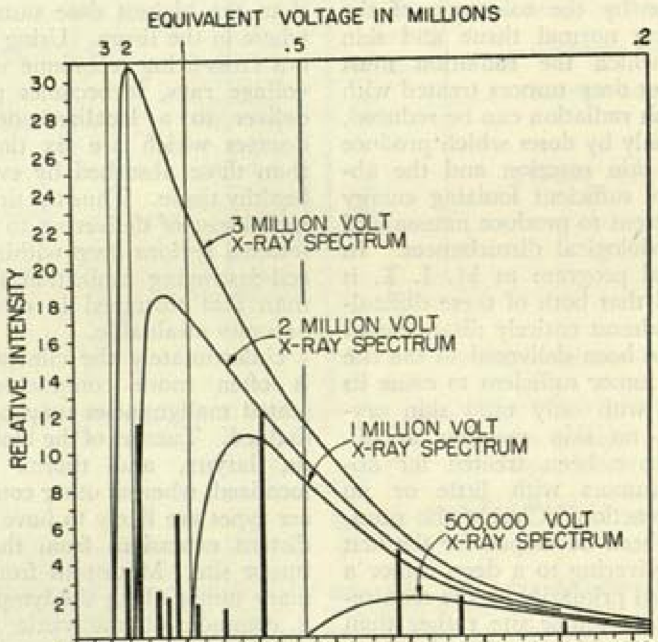
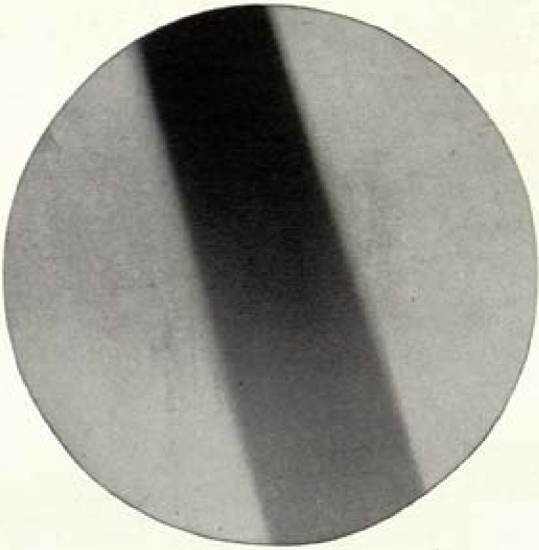


Figure 2.—When high-energy electrons are stopped on impact with a gold target, their kinetic energy is converted into penetrating electromagnetic radiation. The effect of increasing the voltage is to move the continuous X-ray spectrum in the direction of shorter wave lengths and to increase efficiency of X-ray production. The curves show that the spectrum of 3-million-volt X-rays includes wave lengths shorter than those emitted by radium in equilibrium with its products, as shown by the line spectrum. Such radiation is, therefore, superior to radium in its penetrating, nonscattering properties.

Pioneering work in radiation with X-rays produced by over 1 million volts was made possible by the M. I. T.-designed air-insulated electrostatic generator at the Huntington Memorial Hospital. More than 1,000 patients have been treated with this unusual equipment which established many of the advantages of supervoltage radiation for deep cancer therapy.

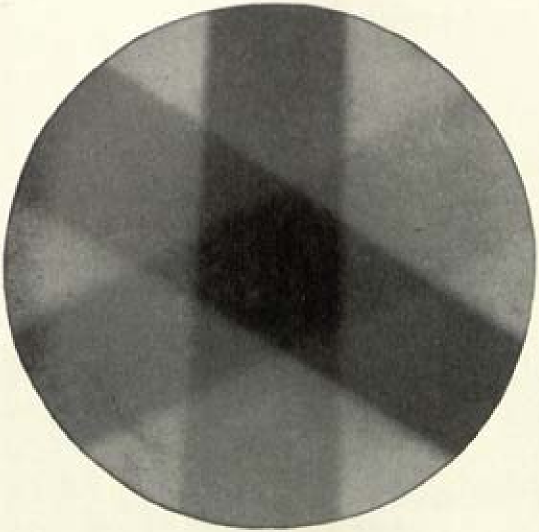
Exterior of the Hyams Building which houses the 3-million-volt X-ray and cathode-ray generator used in clinical research at M. I. T.

The column and terminal structure of the 3-million-volt generator at M. I. T. with its tank removed. This generator produces voltages over 10 times higher than the standard voltage for deep X-ray therapy. Its radiation output, more penetrating than gamma rays of radium, is equivalent to several times the total world supply of that precious material.

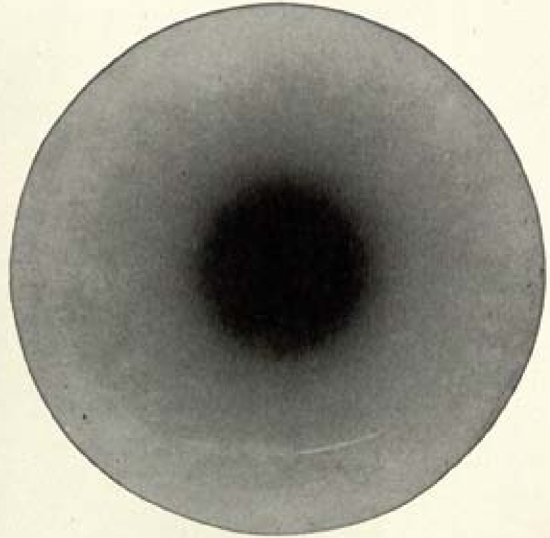


This circular radiograph and the two shown on plate 5 illustrate the technique of cross-firing with one- three- and continuous-portal radiation, as described under each of the separate illustrations.

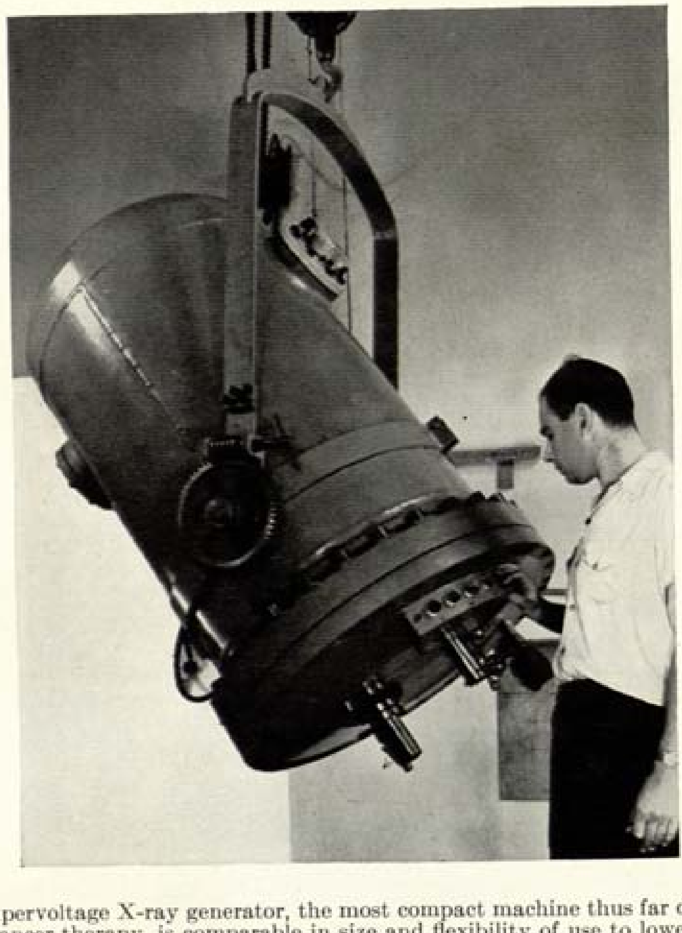
A 2-million-volt beam of X-rays passing through a 20-centimeter cylinder of Masonite representing a phantom patient. In deep X-ray therapy the beam of radiation must enter through the skin and pass through the intervening healthy tissue before it reaches the tumor itself. Supervoltage X-rays produce relatively little reaction on the radiation-sensitive skin, and, because of the higher penetration and lower scattering, are capable of delivering a higher dose to a deep tumor than can be achieved with lower-voltage X-rays.



1. Deep tumor doses can be augmented by cross-firing technique in which the radiation is directed at the tumor from several directions as shown by the dark strips. In the three-portal cross-firing technique the radiation is directed at the tumor from three different angles as shown here. In this case the tumor dose is 60 percent higher than the highest dose sustained outside the selected tumor region.



2. Continuous cross-firing, produced by continuously rotating the tumor-directed beam relative to the patient, results in a uniform tumor dose many times that sustained by the radiation-sensitive skin and several times that sustained by healthy tissue adjacent to the tumor. Supervoltage radiation, combined with cross-firing technique, makes possible high efficiency in treating localized deep tumors.



This supervoltage X-ray generator, the most compact machine thus far developed for cancer therapy, is comparable in size and flexibility of use to lower-voltage equipment now generally available. It was developed at M. I. T. under a grant by the American Oncologic Hospital which will use it in its program of deep therapy.

generator which has been designed since the war in Dr. Van de Graaff's laboratory is being reproduced in several of the world's principal nuclear research laboratories, among them Cockcroft's National Nuclear Laboratory at Harwell, England, Joliot's laboratory in the College de France in Paris, and the National Research Council's Chalk River Laboratory in Canada. Several dozen electrostatic accelerators scattered about the world, notably including those designed by Prof. R. G. Herb at the University of Wisconsin, have been used in research which has made important contributions to the knowledge of nuclear processes.

Back in 1934 the realization that electrostatically generated voltages could also be used in the production of unusually penetrating X-rays for deep therapy led to the opportunity to build the 1-million volt air-insulated generator for the Huntington Memorial Hospital. This machine and its building were financed by the Godfrey M. Hyams Trust, a Boston philanthropy which has continued loyally to support the high-voltage medical work at M. I. T. On March 1, 1937, the first patient was treated at the Huntington, and during the subsequent 4½ years well over 1,000 patients were given complete treatment series. This pioneering effort in radiology disclosed at an early date the great benefits that could be derived in avoiding skin damage and increasing the depth dose by use of roentgen rays produced by several times the standard voltage. In 1939 development of a compact 1¼-million-volt gas-insulated X-ray source was undertaken for the Massachusetts General Hospital. This generator was placed in use in April 1940, and has since been in continuous clinical use. Between 15 and 25 patients are treated daily with the equipment developed and built at M. I. T., and the voltages now generally used with this apparatus lie in the range between 1¼ and 1½ million volts. This work has further confirmed the desirability of supervoltages in the treatment of certain types of malignancies and has emphasized the need to investigate the efficacy of roentgen rays produced at still higher energy levels. The electrical engineering group at M. I. T. extended its efforts to the development of a higher-voltage X-ray source for Philadelphia's American Oncologic Hospital. The first generator for Oncologic, completed during the war, was requisitioned by the United States Army for nuclear research at Chicago. Its successor, a tiltable 2-million-volt unit now nearly ready for delivery, is the most compact supervoltage X-ray source yet seen. Meanwhile, the supervoltage X-ray generator at Technology has made possible the extension of pioneering clinical researches to 3 million volts and is now being modified to bring the voltage to 5 million volts.

Present Therapy Spectrum

At no time in medical history have so many types of ionizing radiation been available for therapy and research. Artificially radioactive substances produced within the nuclear pile or by the cyclotron, roentgen rays produced by betatrons with energies up to 100 million volts, high-energy cathode rays, and well-collimated beams of neutrons and protons are all under investigation or proposed for use on the deep-tumor problem. Artificially radioactive substances are of unique and fundamental importance as tracers in biological and clinical research, but only a few materials such as radio-iodine and radio-phosphorus have thus far found limited therapeutic use. Roentgen rays with energies much higher than a few million volts may actually become less desirable for therapy because of the increasing narrowness of the radiation beam at the very high energies and the seriously high exit dose which once again produces skin damage. High-energy cathode rays, which behave like bullets in the sense that they produce no damage in the body beyond their maximum range, are still too new

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to be fully evaluated, but may find an important place in the future. Cyclotron-produced neutron beams have been investigated for about 10 years at the University of California with interesting but inconclusive results to date. While all this spectrum of ionizing radiations will need to be thoroughly studied, it is already clear that roentgen rays produced by a few million volts have the most direct connection with the extensive roentgen-therapy experience of the past and offer very significantly improved properties for the treatment of deep malignant tumors.

Electrostatics in Production

Only a few supervoltage equipments constructed by skillful experimenters have thus far been available for research and medicine. With increasing recognition of the unique capabilities of electrostatic accelerators, there developed a corresponding need for a reliable commercial source of such devices. Toward the end of 1946, after efforts to utilize existing companies, the High Voltage Engineering Corp. was organized in response to this urgent requirement. Located in a plant near Harvard University, staffed in part by men who participated in the wartime electrostatic program of the Institute and with consultants from M. I. T., the University of Wisconsin, and Rice Institute, this company has gathered the best scientific experience in this important and difficult technique for the benefit of science and medicine. The new enterprise was financed by the American Research and Development Corp., recently organized by leading New England citizens, including Senator Ralph E. Flanders of Vermont and Harvard's General Georges F. Doriot, who is its president. Advised by Technology's president, Karl T. Compton, Prof. Edwin R. Gilliland, '33, of the Department of Chemical Engineering, Jerome C. Hunsaker, '12, head of the Departments of Aeronautical and Mechanical Engineering, and others, the American Research and Development Corp. has the purpose of encouraging the development of new industries with strong roots in science. No organizational or financial connection exists between Technology and the High Voltage Engineering Corp., but a mutual appreciation of the need for adequate commercial development of the products of scientific research has created an atmosphere of common endeavor. The High Voltage Engineering Corp. is headed by Dr. Denis M. Robinson, who was Commonwealth fellow at M. I. T. in 1929, scientific representative of the Telecommunications Research Establishment (Britain's radar development laboratory) assigned to the Radiation Laboratory at M. I. T. during the war, and in the first postwar year chairman of the Department of Electrical Engineering at the University of Birmingham in England.

Typically a product of modern times, the High Voltage Engineering Corp. is building the latest tool for medical science against cancer—a compact 2-million-volt X-ray source fully as flexible as conventional lower-voltage equipments. Such 2-million-volt generators, engineered for therapy and science, are already scheduled for shipment to leading medical and research institutions in England, France, and the United States. At the same time, recognizing that it possesses the knowledge and ability for creating one of the most powerful tools for nuclear research, this company is undertaking the production of electrostatic positive-ion accelerators of still higher energy rating. It is hoped that by this means not a few of the products of fundamental science and engineering may become available for the full use and benefit of all mankind.

The Optical Glass Industry, Past and Present[1]

By Francis W. Glaze, *Technologist, National Bureau of Standards*

[With 4 plates]

The earliest lenses known to have been employed were probably hand magnifiers, as both Seneca and Aristophanes mention them. Quartz and glass lenses have been unearthed from the ruins of Nineveh, Pompeii, and Herculaneum. Ptolemy, A. D. 100, wrote a whole book on optics.

A portrait, painted in 1352, shows two mounted lenses with handles riveted together, in front of the eyes of the subject. The invention of printing by Gutenberg, in the middle of the fifteenth century, stimulated the use of such spectacles; but, even so, it was not until 1760 that Benjamin Franklin invented the first pair of bifocal spectacle lenses.

It seems likely that the increasing use of spectacles furnished the impetus, directly or indirectly, for the development of both the microscope and the telescope. Some authorities credit the invention of both instruments to Johann and Zacharius Jansen in 1590, while others give credit to Hans Lippershey or James Metius of Alkmaar for the creation of the telescope about 1608. In any case, between 1590 and 1620, interest in the telescope developed rapidly. This early work on the telescope was with the refractor type of instrument. It was not until 1670 that Sir Isaac Newton described to the Royal Society the first reflecting telescope and also demonstrated its use. However, a similar type of instrument had been described by James Gregory in his Optica Promota in 1663. Another type of reflecting telescope was invented in 1672 by Cassegrain.

During the next 200 years many improvements were made in optical instruments, thereby giving great impetus to the search for better optical glass. Its quality was greatly improved by the discovery, in 1790, of a method of producing a glass chemically homogeneous and substantially free from imperfections such as "stones" and bubbles. This invention and much of its subsequent development must be credited to Pierre-Louis Guinand, a Swiss watchmaker, and his descendants and their associates. They found that chemical homogeneity could be obtained by stirring the molten glass and also discovered means of annealing the resultant product. Later Guinand worked with J. Fraunhofer in Bavaria. The latter ultimately attained considerable success and produced telescope disks up to 28 centimeters (11 inches) in diameter. He further initiated the specification of refraction and dispersion in terms of certain lines of the spectrum and he even attempted an investigation of the effect of chemical composition on the relative dispersion produced by glasses in different parts of the spectrum.

One of the associates of the Guinand family, Bonteps, was forced to flee to England in 1848 because of political

[1] Reprinted by permission from Sky and Telescope, vol. 6, No. 3, January, and No. 4, February, 1947.

troubles. There he became connected with Chance Bros., still one of the better-known manufacturers of optical glass. E. and C. Feil, great-grandsons of Guinand, worked with E. Mantois; this association later developed into the famous French optical glass company of Parra-Mantois. In 1887, Edmond Feil, a son of C. Feil, went to England where he offered his knowledge to Chance Bros.

Although much work was done by Faraday and Harcourt in England more than a hundred years ago, the outstanding study of the relationship between composition and optical constants was carried out by O. Schott in an effort to develop glasses having the optical properties desired by Professor Abbe of the University of Jena, who was trying principally to develop better microscope objectives. Except for a limited number of coloring agents, the compounds of only five or six elements were in general use prior to 1880. Only two types of optical glass were known: crown, a lime glass, and flint, a lead glass. There were many shortcomings in lenses which simple combinations of these two types of glass could not overcome. Through the work of Schott and his collaborators at Jena, about 25 new elements or their compounds became available to the glass industry. Also, from this work developed the famous optical glass plant of Schott and Genossen. Schott discovered that the glasses compounded with these new materials possessed a wide range of optical properties, and this discovery made it possible to build up optical systems free from the defects previously exhibited.

As nearly as can be determined, the first successful manufacture of optical glass in the United States was by Macbeth & Co. of Pittsburgh, Pa., about the year 1893 (possibly earlier). It is in this connection that we next hear of Edmond Feil, as superintendent of the firm's optical glass factory. This plant, according to Chance, finally managed to make "some beautiful glass of great purity and reasonably fine quality of annealing."

Evidently Feil did not remain with Macbeth & Co. long, for in 1897 he was working with the Manhattan Optical Co. and operating a small glass plant at Cresskill, N. J. Their specialty was lenses for photographic purposes. Production started about 1896 and continued for approximately 6 years, after which the Manhattan Optical Co. combined with the Gundlach Manufacturing Co. of Fairport, N. Y., and the glass plant ceased operation. Thus it seems that the manufacture of optical glass in this country was undertaken with the assistance of a direct descendant (the great-great-grandson) of Pierre-Louis Guinand, one of the earliest workers in the field.

The National Bureau of Standards entered the field, in a preliminary way, at its Pittsburgh laboratory in July 1914, under the direction of P. H. Bates, who retired from the Bureau shortly after VJ-day. Just prior to this (about 1912), the Bausch & Lomb Optical Co. started work in the same field. Both of these organizations have been producing glass ever since.

It is evident from the foregoing that the manufacture of optical glass in the United States is a modern industry. Also, it is only an industry of moderate size except in wartime, as can be seen from the accompanying table.

TABLE 1.—*Production of optical glass in the United States during World Wars I and II, in pounds*

World War I		World War II	
1917:			
April	2,850	1938	61,000
July	4,800	1939	145,000
October	15,645	1940	260,000
		1941	801,000
1918:		1942	2,851,000
January	35,955	1943	3,688,000
April	24,363		
July	55,355		
October	79,275		

There are no accurate figures for the production of optical glass for the years 1917–37 inclusive. However, it is safe to say that it did not appreciably exceed 61,000 pounds (1938 production) for any year during that period.

Optical glass, as used in lenses, functions as a medium to refract the rays of light from any distant object so that they will converge to a single corresponding point in the image. This requirement is extremely difficult to meet and demands that the glass in each lens (or prism) element be of uniform quality throughout and that its optical constants agree very closely with those of certain standard types of glass. To manufacture on a large scale a series of different types of glass of this degree of perfection requires close attention to details.

The characteristics of good optical glass are:

1. Homogeneity.
   a. Uniformity of chemical composition, including freedom from streaks of different compositions within the glass mass (striae).
   b. Freedom from seeds, or bubbles.
   c. Freedom from included fragments of undissolved material or crystallites within the glass mass (stones).
   d. Freedom from cloudiness.
2. Definite refractive indices for different wave lengths of light.
3. Freedom from color.
4. High degree of transparency.
5. High degree of chemical and physical stability.
   a. Resistance to action of weather and certain chemical agents.
   b. Toughness and hardness.

The art of making optical glass of the above characteristics is the subject of the following necessarily general account.

Practically all optical glass in the United States is made in pots which are used only once. Hence, the first requisite is a pot of the necessary refractoriness. And here we run into one of the main compromises necessary in connection with optical glass production. The denser or less porous a pot body is, the less it is attacked by the glass or its batch. But, the denser the pot body is, the more sensitive it is to thermal shock (sudden temperature change). So the type of body finally selected is somewhat less than the ideal both as to corrosion resistance and resistance to thermal shock.

The pots are made up essentially of four constituents: feldspar, ball or bonding clay, kaolin, and grog (old pot body). The porosity of the pot body is controlled by the particle sizes of the grog used. In this country all pots are cast in a mold made of plaster of Paris. For the more corrosive glasses, pots are made more resistant by means of a dense lining. This provides the resistance to shock of a porous body and the resistance to corrosion of a dense body. After the pot has dried sufficiently so that it can be handled, it is removed from the mold and air-dried for 3 weeks or more. It is then ready to set in the pot arch for burning (pl. 1, 1). This burning takes anywhere from 48 to 100 hours, depending on the density of the pot body, for pots of approximately 7 cubic feet capacity such as are used at the National Bureau of Standards. Of course, the denser the pot body, the more slowly it should be burned. The pot can be fired completely in the pot arch or it can be partially fired in the pot arch and the firing completed in the melting furnace.

The transfer of the pot from the pot arch to the melting furnace is accomplished by means of a pot carriage. This is equipped with a pair of massive tongs operated from the rear of the carriage, and with a counterweight which can be moved along the carriage to balance the weight of the pot of glass. The melting furnace is generally regenerative—that is, built over two chambers of checkerwork which are alternately heated by the gases of combustion and then used to heat the incoming air necessary for combustion. The fuel usually used is gas, preferably natural gas.

After the pot has been completely fired at the melting temperature of the particular glass it is designed to hold, it is ready to receive the batch

and cullet (waste glass from previous melts) (pl. 1, 2, right). The time necessary to fill a pot with batch varies from 5 to 10 hours. The temperature of the melting furnace during this operation may be as low as 1350° C. or as high as 1450° C., depending on the difficulty with which the batch melts. After the batch has melted down and foaming has ceased, the stirring of the molten glass can be started. This is accomplished by means of a thimble made of the same materials as the pot, actuated by means of a water-cooled rod driven by a horizontal rotating drum and working over a pulley or a guide as a fulcrum (pl. 1, 2, left).

As soon as the molten glass is reasonably free of seeds or bubbles of gas, it is gradually cooled to the temperature at which the pot of glass should be removed from the furnace. As the molten glass cools down, the rate of stirring must be decreased so that air will not be sucked into the glass in the wake of the stirring rod. Here is another example of compromise. If the rate of stirring is too fast, a seedy but homogeneous or striae-free glass is generally obtained; if it is too slow, a seed-free but striated glass results. The pot of glass is allowed to cool in the melting furnace until the viscosity increases to such an extent that any further stirring might ruin the glass. This temperature is the most critical and may vary from 950° to 1100° C., depending on the type of glass. The time required to produce a pot of glass at the National Bureau of Standards varies from 19 to 28 hours.

After the pot of finished glass is removed from the melting furnace (pl. 2, 1), the bottom of the pot is cooled by means of a blower until the glass is stiff enough so that there will be no movement of the contents due to convection currents. The pot is then covered with a thermally insulated can so that the glass will cool slowly enough to crack into fairly large chunks. The pot is then broken open, the pot body processed for grog, and the chunks of glass saved for further processing. Any imperfections present are trimmed from the chunks of glass by means of steel hammers or diamond saws (pl. 2, 2). These chunks are then broken or sawed to a convenient size for molding into the blanks on order.

These pieces of glass are now put into a preheating furnace where they are gradually heated up to a temperature just below the softening point of the glass. They are picked up by the molder on the end of a steel rod (punty rod) and then heated well above their softening point in a molding furnace and worked into the proper shape for molding. When properly shaped and at the proper temperature, each gob of glass is held over the steel mold and the proper amount of glass is cut off by a pair of shears and pressed into shape. Upon removal from the mold, each blank is placed in a cooling lehr and cooled slowly to prevent cracking.

The above molding procedure is the best for medium-size and large blanks. In the case of small blanks it is best to mold slabs of proper thickness, break each slab into cubes weighing a little more than the desired blank, and then adjust to correct weight on a grinding wheel, especially rounding off all corners and sharp edges. The pieces of glass are fed into a small paddling furnace, gradually brought up to molding temperature, worked into approximate shape by means of paddles, and pulled into the steel mold and pressed. To keep them from cracking the blanks are then placed in an oven attached to the paddling furnace.

In the case of blanks too large to work by hand, the glass pieces are placed in a ceramic mold and gradually brought up to a sufficiently high temperature so that they will soften and flow into the shape of the mold. They are then slowly cooled so they will not crack (a rough annealing).

In any case, the blanks are then inspected. They are immersed in a liquid of index of refraction similar to that of the glass. In such a liquid the

glass surfaces disappear and the imperfections in the interior become evident under proper illumination. The blanks are also gaged for conformity with specifications, those undersize being marked for salvage into smaller blanks and those oversize for grinding to size. The rest are ready for annealing.

The annealing of optical glass is a critical process. Blanks of widely different weight require a different annealing schedule even though they are both made of the same glass. Also, each type of glass has its own annealing schedule except where two glasses are similar in composition. The blanks are loaded into an iron box on perforated iron trays with an air space between the layers. The use of the box and trays gives much better temperature distribution throughout the annealing furnace. The furnace is gradually raised to the annealing temperature and held at that temperature until, from experience, it is known that the glass in the furnace is free of strain. Now it becomes necessary to cool the furnace at such a rate that no strain will be introduced because of temperature gradients within the glass. The cooling rate is very slow at first and is gradually increased as the temperature drops. If properly annealed, an optical element should show no distortion throughout its life.

The final process before shipment or grinding and polishing is the inspection for strain. The blanks are again immersed in a liquid of index of refraction similar to the glass and examined with polarized light. If the glass is perfectly annealed, the area of the glass appears the same as the adjoining background. Otherwise, an interference figure is obtained. This interference figure is compared with that for standard strain samples to determine if the annealing is satisfactory for optical purposes. If not, the blank must be reannealed.

And so, after about 1 month, the batch that was put into the pot appears as a satisfactory finished blank, ready for grinding and polishing into an optical element. In other words, there is present in a plant producing optical glass a month's production of glass. Also, only about 15 to 18 percent of the glass melted is satisfactory for grinding and polishing; hence the high cost of good quality optical glass.

At the National Bureau of Standards 28 different types of optical glass have been produced with indices of refraction ranging from 1.511 to 1.754 and with nu-values from 64.5 to 27.7 (see fig. 1). The nu-value is the reciprocal of the dispersive power of the glass. There are three wave lengths that are especially important in the measurement of refractive index, i. e., the sodium D line, 5893 angstroms, in the central region of the visible spectrum, the hydrogen C line (H-alpha), 6563 angstroms, in the red, and the hydrogen F line, 4862 angstroms, in the blue. When the mean refractive index is given, that for the sodium D line is meant. For each type of glass there is a definite relationship between the indices of refraction for the three spectral lines mentioned. The reciprocal of the dispersive power instead of the dispersive power itself is used in order to avoid fractional values. A high nu-value represents a low-dispersive power and a low nu-value a high dispersive power.

For glasses of index of refraction less than about 1.555, the allowable tolerance is 0.001 of index either way; for those above 1.555 it is 0.0015. The allowable tolerances for the nu-value vary somewhat. For nu-values above approximately 50.0, it is 0.4 to 0.5 either way, depending on the type of glass. Below 50.0 it is 0.3. The light absorption of all types of optical glass except dense and extra dense flints and dense barium crowns must not exceed 1 percent per centimeter of light path measured in white light (generally it is only half of that value). For dense and extra dense flints and dense barium crowns, 2 percent is allowed, although it practically never exceeds 0.8 percent.

Freedom from seeds or bubbles is desirable for the sake of appearance, but it is not necessary except in reticles or windows and other elements in a tocal plane. Appearance, therefore, poses quite a problem for the glassmaker because the barium glasses so necessary in photographic objectives today are especially difficult to make seed-free.

As can be seen from the foregoing, the production of glass for the ordinary types of optical instruments is fraught with many difficulties. And when the glassmaker is called upon to produce lenses or mirrors for astronomical telescopes, his problems are increased manyfold. It will be the purpose of the remainder of this paper to show how these difficulties were overcome, first at the National Bureau of Standards and, later, at the Corning Glass Works.

Although there have been some notable large lens blanks made in Europe, the most famous being the 40-inch refractor of the Yerkes Observatory at Williams Bay, Wis., the larger telescopes are all of the reflecting type.

The manufacture of a large lens necessitates a single large chunk of perfect optical glass which must then be brought to the required shape by heating and softening it in a ceramic mold of proper size. Such large chunks of glass are extremely difficult to obtain, usually requiring many melts of glass. Upon examination of the resultant lens, it may be found to be unsatisfactory, and all the work has to be done again. Nor are the difficulties over even then. To complete the lens requires the accurate grinding and polishing of two faces. For a mirror for a reflecting telescope, only one face of the disk has to be ground and polished. Also, the glass for the disk may contain considerable seed and striae unless they are on the surface and interfere with the figuring

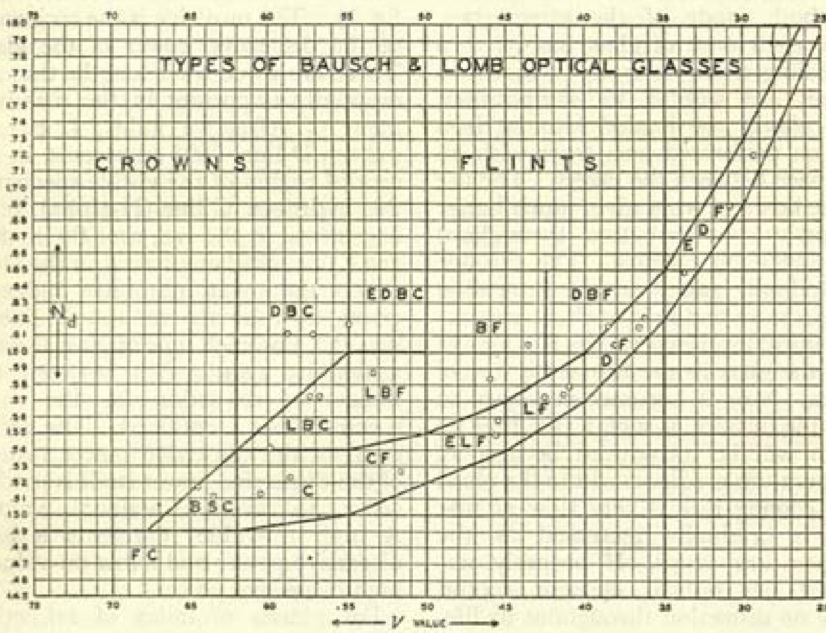
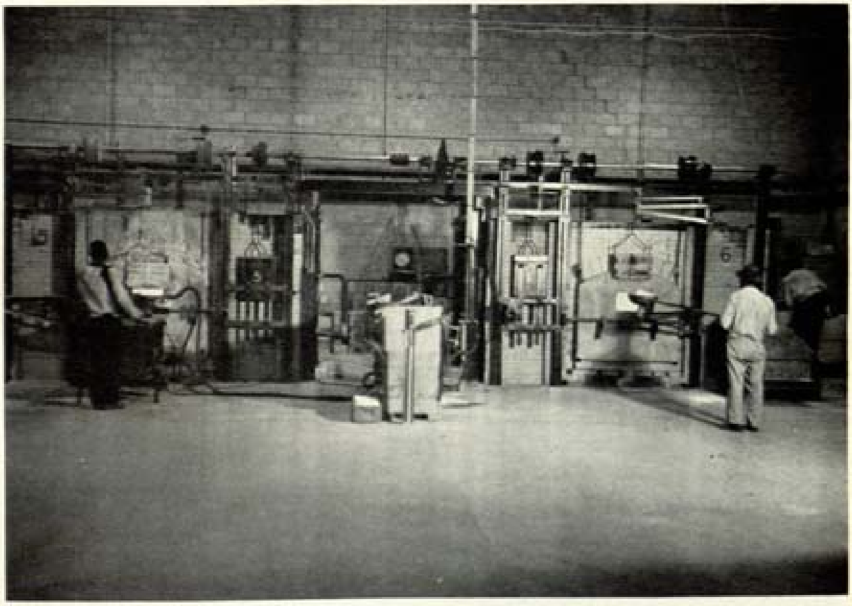


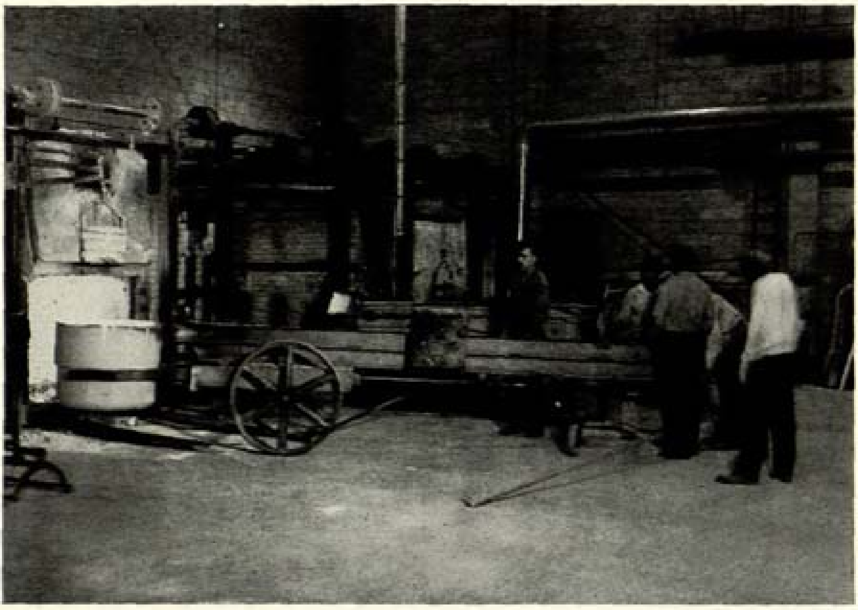
FIGURE 1.—Chart showing relation of index and reciprocal dispersion of the common types of glass. Most glasses lie near a curve in which dispersion increases with index; glasses far off this curve are especially useful to the designers of optical systems. Diagram courtesy Bausch & Lomb Optical Co.

1. AN OPTICAL GLASS POT, AND ITS STIRRING THIMBLE, SET IN A POT ARCH PREPARATORY TO BURNING



2. TWO MELTING FURNACES AT THE NATIONAL BUREAU OF STANDARDS

The pot of glass in furnace 5 is being stirred and its temperature is being determined by the furnaceman by means of an optical pyrometer. The pot in furnace 6 is being filled with batch. Photographs courtesy National Bureau of Standards.



1. REMOVAL OF A POT OF FINISHED OPTICAL GLASS FROM THE MELTING FURNACE

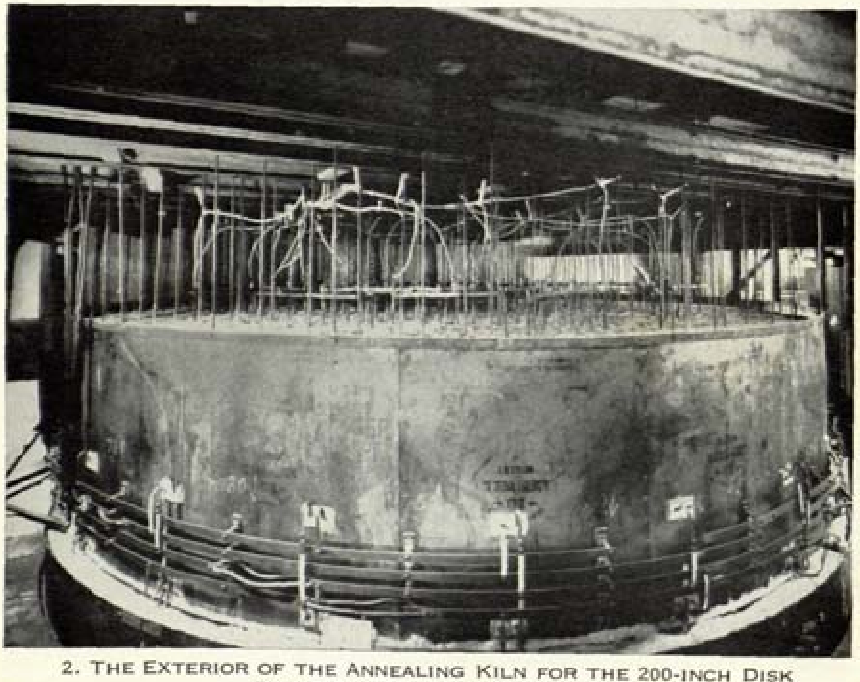
2. CUTTING OPTICAL GLASS BY MEANS OF A 24-INCH DIAMOND SAW

CASTING THE 70-INCH DISK OF OPTICAL GLASS

The molten glass is flowing down the metal trough from the pot into the combined mold and annealing furnace.

1. THE 70-INCH DISK BEING EXAMINED, PRIOR TO SHIPMENT, BY DR. G. K. BURGESS, THEN DIRECTOR OF THE BUREAU OF STANDARDS, AND PROF. C. C. CRUMP, FORMER DIRECTOR OF THE PERKINS OBSERVATORY

The 8-inch core is resting on the surface of the disk.



2. THE EXTERIOR OF THE ANNEALING KILN FOR THE 200-INCH DISK

Photograph courtesy Corning Glass Works.

of the mirror. Because of this simplification the largest telescopes are reflectors.

Except for two disks, one 23 inches in diameter made in 1889 and one 60 inches in diameter made in 1895, the manufacture of telescope mirror blanks was also considered a European monopoly until 1926. In that year, Ohio Wesleyan University asked the National Bureau of Standards to make a blank 70 inches in diameter. Such a disk, assuming the thickness to be one-sixth the diameter, would be 11 inches thick and weigh about 4,000 pounds.

The type of glass decided on was an ordinary borosilicate crown. The batch was melted in a pot holding approximately 5,000 pounds of glass, near the bottom of which was a hole stoppered with a water-cooled metal plug. After the batch had completely melted, stirring was started and continued for 6 hours, after which the temperature was reduced from 1400° to 1350° C. While the pot was filled, current was applied to the heating elements of the combination mold-annealing furnace.

When arrangements were completed for tapping the pot, the water-cooled plug was removed and the glass flowed by means of a trough into the mold-annealing furnace (fig. 2 and pl. 3). After practically all the glass was in the mold, the trough was removed and the top of the annealing furnace placed in position.

Thirty-three hours after pouring, the insulation over the top of the annealing furnace had been built up to the 12 inches that covered the rest of the furnace. The loss of heat became so slow then that no current was necessary for 4 days; it was not until 8 days after casting that the average temperature of the furnace reached 600° C. During the next 2 months, the temperature of the furnace was gradually reduced to the annealing temperature of 461° C., which was then maintained for 41 days.

Assuming now that the disk was free from strain, it was still necessary to cool it so slowly that no great amount of strain would be present at the end of the process. Although the data of L. H. Adams and E. W. Williamson indi-

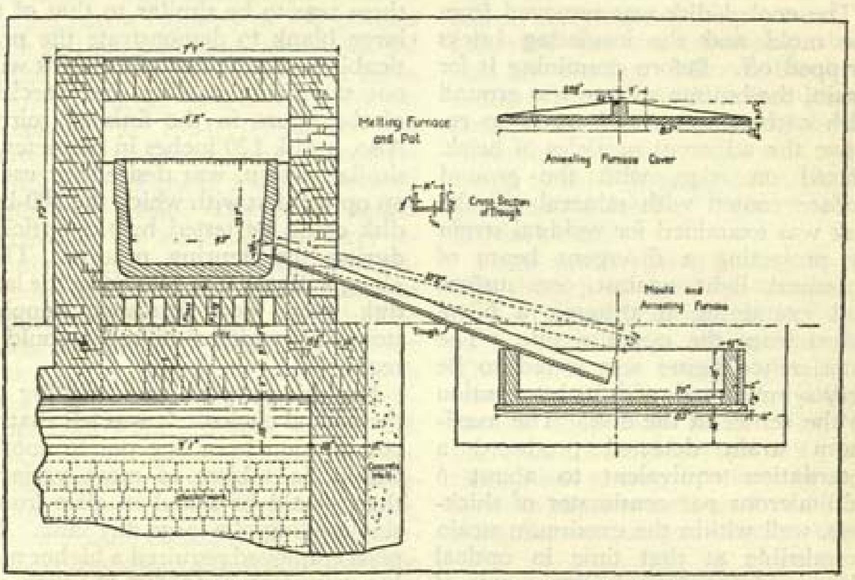


FIGURE 2.—The essential features of the equipment for the 70-inch disk, shown in use in plate 3.

cated that an initial cooling rate of 2.33° C. per day and a maximum rate of 60° C. per day would be permissible, it was decided to use an initial rate of about 1° C. per day and a maximum rate of not over 10° C. (preferably 6° C.). The reason for such conservatism was that Adams and Williamson's findings were based on the annealing of much smaller pieces of glass, and that the validity of extrapolations from data obtained on small pieces to the case of a much larger piece was questionable.

The cooled disk was removed from the mold and the insulating bricks stripped off. Before examining it for strain, the bottom surface was ground with carborundum and water to remove the adherent particles of brick. Placed on edge, with the ground surface coated with mineral oil, the disk was examined for residual strain by projecting a divergent beam of polarized light against one surface and examining it through a Nicol prism from the opposite side. The interference figure was found to be very symmetrical, with its intersection in the center of the disk. The maximum strain detected produced a retardation equivalent to about 6 millimicrons per centimeter of thickness, well within the maximum strain permissible at that time in optical glass used for optical instruments of highest precision.

All that remained was to cut the 8-inch hole for the Cassegrainian mounting (see pl. 4, 1). This was accomplished in about 70 working hours and without any unforeseen difficulties. So ended an operation that took over 15 months: 6 months and better for making and air-drying the pot; about 15 days for burning the pot, melting, and pouring; 7½ months for annealing and cooling; and for strain inspection and cutting the hole, spare time as it became available. And this does not include the time necessary for making and drying the mold for the pot.

The task presented to the Corning Glass Works by the California Institute of Technology in 1931 was to make a mirror blank of low-expansion borosilicate glass and of sufficient size to produce a telescope disk 201 inches in diameter of materially less weight than the 40 tons which would result from the customary thickness of one-sixth the diameter. As an aid to proving the feasibility of whatever program might be adopted for manufacture, the Observatory Council of the California Institute of Technology ordered two small disks of 30 and 60 inches in diameter, respectively. The design of these was to be similar to that of the large blank to demonstrate the practicability of reducing the weight without sacrificing rigidity and precision of the figure in the finished mirror. Also, a disk 120 inches in diameter, of similar design, was desired for use as an optical flat with which the 200-inch disk could be tested by the opticians during the figuring process. Thus, along with the task of making the large disk, there were furnished steppingstones by which fulfillment could be reached.

For this purpose, tank melting was the logical choice. It was felt that the composition from one pot to another would be subject to more variation than would be found in glass from a single filling of a large day tank. The glass employed required a higher melting temperature (1580° C.) than was obtainable with available pot furnaces. Also, ladling equipment was less costly than installing means for pouring the glass from pots. Ladling permits one to rake the surface of the bath when necessary to free it of objectionable scum or floating stones before filling the ladle. It also affords an opportunity to inspect the quality of the glass prior to pouring it into the mold.

The mold was complicated because of the ribbed structure required in the lower portion of the finished disk. The cores were made of high-temperature insulating brick of standard size laid with high-temperature cement, and they were anchored to the iron bedplate of the mold by means of a

heat-resisting alloy. The anchors were provided with adequate air cooling. This maintained the temperature safely below that at which the tensile strength of the anchors could not withstand the buoyant force of about 300 pounds on the largest cores for the 7 hours necessary for the casting operation.

The pouring oven over the mold had three ladling holes and was heated with natural gas to keep the glass sufficiently fluid to flow to all parts of the mold. The three ladles used in casting had a capacity of 750 pounds each and the ladle skins were returned to the tank in order to conserve glass.

After pouring was completed on December 2, 1934, the mold was moved on rails to the annealing position by means of a hand-operated drum and cable. The entire upper portion of the annealing furnace, including top and side walls, was suspended like the pouring oven and was electrically heated (pl. 4, 2.) The lower portion of the annealing furnace was built on the screw hoist beneath the mold. The two portions telescoped for some distance as the disk was raised into the annealing position.

During the soaking, or constant-temperature period of annealing, which required about 50 days, controllers automatically maintained the temperature at the desired value. For the 200-inch disk, 26 inches in thickness, the cooling rate was maintained at 0.72° C. per day from the initial temperature of 500° C. until 300° C. was reached. Below the latter value, a more rapid cooling rate was possible. About 10 months were required to reach room temperature.

To some extent, the task of making these disks was lessened by the choice of a Pyrex-type of glass. Its coefficient of expansion, only 2.5×10^{-6} cm. per °C. per 1 cm. length against 8.5×10^{-6} cm. per °C. for ordinary borosilicate crown, greatly reduced cooling stresses and shortened annealing times. On the other hand, it added materially to the difficulty of melting and working. The successful fabrication of large disks cannot be ascribed wholly to the use of low-expansion glass. The same methods of manufacture outlined here would produce disks of ordinary crown glass with greater ease of melting and casting. The time required to anneal such glass, however, would be increased nearly fourfold, and greater demands would be made on the temperature-control equipment to maintain the corresponding slower rate of cooling. Mirror blanks of ordinary crown would be heavier and, because of the higher coefficient of expansion, would require a much longer time for grinding and polishing. This took a total of 3 years for the 200-inch disk.

From the foregoing it can be seen that there is no need for astronomers of the United States to go to Europe to fill their needs for optical glass. There is in this country the "know how" to fill their wants, fantastic though they may seem. The field has been thoroughly explored. Practically no money or time need be spent in experimental work to develop a satisfactory method of procedure.

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The Age of the Earth[1]

By ARTHUR HOLMES, *Regius Professor of Geology, University of Edinburgh*

[With 2 plates]

Long before it became a scientific aspiration to estimate the age of the earth, many elaborate systems of world chronology had been devised by the sages of antiquity. The most remarkable of these occult time scales is that of the ancient Hindus, whose astonishing concept of the earth's duration has been traced back to the Manusmitri, a sacred book that was probably completed in its present form about 150–120 B. C. According to this venerable compilation of law and wisdom, the whole past and future of the world is but a "day" in the eternal life of Brahma—a Day of 4,320 million years, throughout which finite things are being created out of the infinite. The Day of Brahma is divided into 14 great cycles, each lasting 308,448,000 years, together with a final "twilight" period of 1,728,000 years, at the close of which, when Brahma's Night begins, the finite is destined once more to merge into the Infinite. At present the world is in the seventh of these cycles and, according to the Hindu calendar recorded in the Vishnu Purana, it is now (A. D. 1947) 1,972,949,048 years since the earth came into existence. By a curious coincidence this characteristically precise assessment is of the same order as the 2,000 million years which has recently been the most widely favored estimate for the age of the expanding universe.

If geological concepts had developed in a community endowed in advance with so generous a concept of the past, much confusion and bitter controversy might have been avoided. But in western Europe the age of the earth had long been identified—to within a few days—with the few thousand years of mankind's history as recorded in the narratives of the Old Testament. On the interpretation of Archbishop Ussher (1581–1656) the creation of the world took place in the year 4004 B. C., and pioneer geologists whose observations suggested that the Mosaic traditions might not be scientifically reliable were branded as dangerous heretics.

A mild though significant instance of the prejudicial influence of this cramping limitation of time is afforded by a remark made by the celebrated astronomer Edmund Halley (1656–1742), in the course of a communication to the Royal Society of a "Proposal . . . to Discover the Age of the World" (1715). Halley realized that the sea had become salt because of the accumulation of saline material contributed by inflowing rivers, and he suggested that the total amount of salt in the sea might therefore provide a measure of the age of the oceans. At that time the necessary data for making the calculation were not available, and Halley lamented that the ancient Greek and Latin authors had not "delivered down to us the degree

[1] Reprinted by permission from Endeavour, vol. 6, No. 23, July 1947. In this reprinting, several passages in the manuscript as originally written, which were omitted in Endeavour, have been restored.

of the saltness of the sea, as it was about 2,000 years ago; for then", he continued, "it cannot be doubted but that the difference between what is now found and what was then, would become very sensible." Now obviously, if Halley had been thinking in millions of years instead of thousands, he must have realized that the increase of salinity since Roman times would be quite undetectable. Nevertheless, he did not fail to slip in his suspicion that "the world may be found much older than many have hitherto imagined."

It was James Hutton (1726–1797) who first clearly grasped the full significance and immensity of geological time. In his famous "Theory of the Earth," communicated to the Royal Society of Edinburgh in 1785, he presented an irrefutable body of evidence to prove that the hills and mountains of the present day, so far from being everlasting, have themselves been carved and are still being modified by slow but inexorable processes of erosion such as those now in operation; and that the sand and mud continually removed by rivers are being slowly deposited on the sea floor as sedimentary rocks in the making. Realizing that "the past history of our globe must be explained by what can be seen to be happening now," and observing that the sedimentary strata of the earth's crust bear all the hallmarks of having accumulated exactly like those now being deposited, he saw that the vast thicknesses of these older strata implied the operation of erosion and sedimentation throughout a period that could only be described as inconceivably long. But Hutton went further. He recognized not only that the earth is a thermally and dynamically active planet, internally as well as externally; he was also the first to demonstrate that the internal activity is of a cyclic character. He saw that the present cycle of erosion—given only time enough—would eventually reduce the most vigorous landscape to sea level, and he deduced from the very existence of landscapes, carved for the most part out of marine sediments, that these sediments must have been upheaved from the sea floor in some former age. In unconformities, such as the classic example illustrated by plate 1, figure 1, he found the "ruins of an earlier world" which had already passed through a similar cycle of upheaval and erosion long before the present one began. The story revealed by the structure and sequence of the rocks at Siccar Point is clear. The lower rocks, now standing nearly vertical, are sediments, which, originally deposited on the sea floor, were subsequently folded by powerful lateral compression. The region of folded and therefore greatly thickened rocks then rose to form a land mass which was attacked by denudation as soon as it appeared above sea level, to be gradually dissected into mountains and valleys and eventually reduced to a plain. As a result of later subsidence, the worn-down surface became an area of deposition, and successive layers of sediment then slowly accumulated over the truncated edges of the older rocks. The plane of unconformity separating the up-tilted rocks beneath from the flat-lying rocks above evidently represents an immensely long interval of time.

Today we know that the earth's history has included a succession of at least 10 of these major cycles, each involving (1) thick accumulations of sediments and volcanic rocks in a subsiding belt of the crust; (2) intense compression of the belt, resulting in folding and crumpling, and accompanied by metamorphism of the deeper rocks and the formation of great masses of granite; and (3) general uplift of the belt and the wearing away of its exposed portions by denudation. The Alps and Himalayas are examples of mountain systems now in stage (3) of the latest of these mountain-building or orogenic cycles, as they are called. The rocks of Cornwall and Devon are relics of the immediately preceding

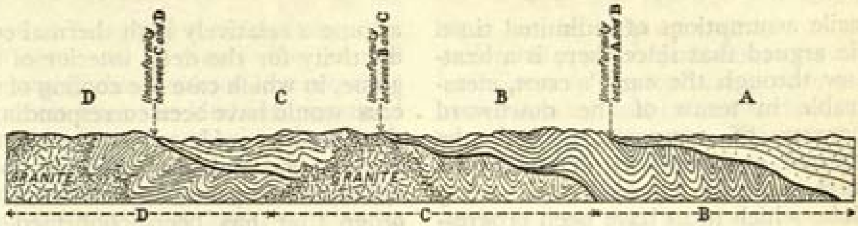

FIGURE 1.—Diagrammatic section to illustrate the rocks and structures of a series of orogenic belts (A, B, C, and D), such as make up the continental crust of the earth. (Vertical scale greatly exaggerated.)

cycle, and those of the Lake District and most of Scotland and Wales and Norway belong to the next earlier one. From beneath the North West Highlands of Scotland and the mountains of Scandinavia the rocks of even older cycles appear (pl. 2, fig. 1). So, going further afield than Hutton, we can travel back through a long series of these contorted records of earth history. But however far we penetrate into the past we still, like Hutton, find "no vestige of a beginning." How this comes about can readily be grasped by reference to figure 1. In every continent the oldest known rocks are found to be metamorphosed sedimentary types which gradually merge into completely reorganized rocks such as granite. The granite, however, instead of being older than the rocks in which it is emplaced, is actually younger, since it crystallized in its present form during or after the folding of the pile of sediments with which it is associated. Everywhere the oldest visible rocks pass sideways or downwards into walls and foundations that are younger than themselves. But since the oldest visible rocks are of sedimentary origin, they must have been derived from rocks of still greater age; from rocks that were reincarnated as granite long ago and of which no other recognizable trace can now be found. Hutton's experience covered only a small proportion of the earth history now known to us, and he was therefore recording no more than the sober truth when he declared he could find "no vestige of a beginning." Unfortunately this conclusion was interpreted by most of Hutton's contemporaries to mean that, according to him, the earth never had a beginning, and so was never created. Thus, far from being welcomed, Hutton's discoveries were generally regarded with righteous horror as being contrary to the Scriptures, while he himself was accused of having "deposed the Almighty Creator of the Universe from his Office." But Hutton was not without a circle of loyal friends and admirers in Edinburgh; the modest fame in which he died 150 years ago soon developed into a world-wide appreciation of his genius.

Hutton himself, in the absence of guiding data, made no attempt to estimate the rates of geological processes. Many of his successors, however, exhilarated by their newly found freedom, became unduly reckless in their extravagant demands for time. In 1859, for example, Darwin estimated from the supposed rate of chalk erosion in Kent that the time required for the denudation of the Weald and the recession of the bordering escarpments of the North and South Downs to their present positions was probably about 300 million years. We now know that this estimate was at least five times too long; but Jukes, commenting on it at the time, thought it quite as likely that the period required might have been a hundred times as long. Evidently 30,000 million years was not considered absurdly excessive for a small fraction of geological time.

Kelvin, one of the great pioneers of geophysics, then entered the field with a dramatic counterblast against such

facile assumptions of unlimited time. He argued that since there is a heat-flow through the earth's crust, measurable in terms of the downward increase of temperature and the thermal conductivities of rocks, the earth could be regarded as a cooling globe which must have been progressively hotter in the past. Beyond the dim horizon of the oldest rocks he envisaged a "beginning" corresponding to the time when the earth was molten and newly born from the sun. In 1862 he set himself the problem of calculating the time that had elapsed since the earth's consolidation. Because of uncertainty in much of the data, he allowed wide limits to his solution, concluding that the observed temperature gradients would have been notably lower than they are if the crust had solidified more than 400 million years ago, and notably higher than if solidification had been completed less than 20 million years ago.

Kelvin's challenge initiated one of the many scientific controversies that enlivened Victorian times. Despite many protests, however, he finally narrowed his limits to 20 and 40 million years (1897). Archibald Geikie pointed out in 1899 that the testimony of the rocks clearly denied Kelvin's thermodynamic inference that geological activities must have been more vigorous in the past than they are today; and that the known sequence of sedimentary strata could not have accumulated within the limits set by Kelvin's solution of the problem. Moreover, James Geikie (1900) showed very convincingly that the crustal compression set up by even 100 million years of cooling would be confined to an outer shell far too thin to accommodate the immense thicknesses of folded rocks involved in the Alps and other great mountain ranges. Evidently some factor—if not more than one—had been overlooked, though few physicists were then willing to admit the possibility of any fundamental mistake. Perry, however, had already heartened the geologists by pointing out that it was allowable to assume a relatively high thermal conductivity for the deep interior of the globe, in which case the cooling of the crust would have been correspondingly slowed down. He saw no reason for denying the geologists anything up to 4,000 million years, an estimate of an order that has been confirmed by Wasiutynski in the course of a recent discussion of the earth's thermal history (1946). Nevertheless, Kelvin's great authority compelled a sort of compromise, and at the turn of the century geologists who claimed more than about 100 million years were thought to be unduly rash. A few, indeed, reluctantly satisfied themselves with a more meager allowance of time, but the majority steadfastly refused to accept Kelvin's results as final. The real flaw in Kelvin's assumptions was disclosed shortly after the discovery of radioactivity, when Strutt (Lord Rayleigh) detected the presence of radium in common rocks from all parts of the world. With the demonstration that the crustal rocks contain radioactive elements and are therefore endowed with an unfailing source of heat, it became obvious that the earth is not living merely on its ancestral capital of internal heat, as Kelvin had confidently believed, but that it has an independent and regular source of income of its own. The abundance of the radioactive elements in the crustal rocks is such that the net loss of heat is extremely low; age estimates based on the rate of cooling are therefore greatly increased. If, for example, nine-tenths of the heat-flow through the crustal rocks is of radioactive origin—and something of this order is consistent with the available evidence—then the alleged 20–40 million years of cooling has to be multiplied by 100 or more.

By this time the minds of the older geologists were no longer attuned to thinking in terms of thousands of millions of years and few of them were prepared to take advantage of the new discoveries. This reluctance was largely due to the fact that in 1898 Joly had resuscitated Halley's sugges-

tion for determining the age of the oceans. Adopting the simple hypothesis that, on average, the annual amount of dissolved sodium removed by rivers from the land has remained constant throughout geological time, he found that about 80–90 million years would be required to furnish the total amount of sodium now present in the oceans. This estimate he shortly afterward increased to 100 million years. A few years later Sollas concluded that the probable limits were 80–150 million years. In 1910 Becker, thinking it likely that the annual increments had been progressively greater in the past, reduced the probable age to about 60 or 65 million years. Indeed, Becker was sufficiently convinced of the validity of these "short" estimates to declare that "radioactive minerals cannot have the great ages which have been attributed to them."

It is therefore of some importance to consider the present status of the sodium method. It appears from recent discussion of the relevant geochemical statistics (see especially Conway, 1942 and 1943) that practically all the "chloridized" sodium in river water represents oceanic salt, either blown inland and washed down by rain, or derived from saline deposits or the pore spaces of sediments. Allowing for such "second-hand" salt, the present annual addition of new sodium is about 6×10^7 tons. Even this figure may be misleadingly high because, as Lane has pointed out, analyses are rarely made of the water from rivers when they are in flood, i. e., when the content of dissolved material is at its minimum. The total accumulation of marine sodium in ocean water and sediments is estimated at about 15×10^{15} tons, less the amount initially present, which may or may not be negligible. Thus, on the assumption of past uniformity, all we can conclude is that the apparent age of the oceans is something of the order of 250 million years. But past uniformity can by no means be assumed. Present rates of weathering and eorsion are far too abnormally high to be representative of the geological past. Mountain ranges and land areas in general are now much more elevated and extensive than has usually been the case. Rivers and groundwaters are therefore unusually active, and, moreover, many of them drain regions that are thickly strewn with easily weathered glacial deposits. Finally, human activities of all kinds—agricultural, engineering and chemical—have still further speeded up the rates of weathering and erosion over widespread areas.

Only a crude attempt can be made to assess the effects of these considerations on the "apparent" age of the oceans. Fig. 1 illustrates the observed fact that the continents are made up of belts of rocks that have suffered intense compression, folding and thickening. If we imagine, going backwards in time, all the folds to be straightened out, then the crustal layer responsible for the continents becomes increasingly attenuated and extensive; so much so that in the early days of geological history this continental layer must have been spread so thinly that its surface would be below sea level and the only lands would be a few volcanic islands. Since then, the continental lands exposed to erosion have on the whole, and despite wide fluctuations, progressively increased in height and area. According to this conception, the quantitative effects of denudation must have gradually increased from almost zero at the beginning to the all-time maximum of the present epoch. Roughly we may reckon that the time-average rate was probably between one-half and one-third of the present rate in respect (separately) of area, height, and relief. That is, it was probably between $(\frac{1}{2})^3$ and $(\frac{1}{3})^3$ of the present rate. The age of the oceans may therefore be anything between 8 and 27 times the apparent age of 250 million years which may itself be a minimum. Obviously the hourglass of sodium accumulation is a hopelessly variable timekeeper. The most that can be said is that its

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present reading is not inconsistent with an oceanic age of a few thousands of millions of years.

What we need for the accurate measurement of such immense periods is a natural process that has operated throughout geological time and has produced measurable results at a known rate, of which the law of variation with time is also known. The decay of the radioactive elements is the only known process that fulfills these stringent conditions. The radioactive methods depend on the transformation of uranium and thorium into helium and lead, and on the accumulation of these stable end products in minerals and rocks that contain the parental elements. Helium, being a gas, is liable to escape, but the lead is much more likely to be retained and so to serve as an index of age. Provided a radioactive mineral such as pitchblende or uraninite has remained unaltered by weathering or other changes, then the amount of radiogenic lead now found within it is a function of (a) the amounts of uranium and/or thorium now present and (b) of the time elapsed since the mineral first crystallized. Fortunately it is possible to discriminate between the radiogenic lead and any ordinary lead that may have been present as an initial impurity in the mineral. The parental uranium contains two chemically inseparable isotopes, UI (or U^{238}) and AcU (or U^{235}), in atomic proportions having the present value: AcU/UI=1/139. Since AcU decays much more rapidly than UI, this ratio was progressively higher in the past. The material results of the atomic transformations can be summarized as follows:

$$U^{238} \rightarrow Pb^{206} + 8\ He$$
$$U^{235} \rightarrow Pb^{207} + 7\ He$$
$$Th^{232} \rightarrow Pb^{208} + 6\ He$$

It will be noticed that in each case a specific isotope of lead is generated. Ordinary lead is a mixture of the same three istopoes, together with a fourth, Pb^{204}, which is not known to be an end product of radioactive decay. Thus, if the lead separated from a radioactive mineral is isotopically analyzed (e. g., by means of the mass spectrograph) and found to contain Pb^{204}, the proportion of the latter provides an index of the amount of ordinary lead that was initially present.

The present rates of production of radiogenic lead are known with a remarkable degree of accuracy, but the question naturally arises, can we be reasonably sure that these rates have remained constant throughout geological time? apart, of course, from the inevitable slowing down due to the wearing-out of the parents. In other words, can we be sure that the physical constants concerned have not varied with time? Fortunately, pleochroic haloes provide us with an unambiguous affirmative. Certain granites contain flakes of brown mica which, under the microscope, can be seen to be sprinkled with dark circular spots (pl. 2, fig. 2, right). These are known as pleochroic haloes and some of them, when highly magnified, reveal a beautifully developed pattern of concentric rings (pl. 2, fig. 2, left). A minute radioactive crystal lies at the center of each halo and the darkening of the surrounding mica is produced by the helium ions (α-particles) that are shot out in all directions. The radius of each ring corresponds to the range of the α-particles from one particular radioactive element. Careful measurements by Prof. G. H. Henderson show that the rings in Pre-Cambrian haloes over 1,000 million years old are just as sharply defined as those in younger rocks, and that the corresponding radii and ranges are identical. Since the range, in turn, depends on the rate of disintegration of the radioactive element concerned, it follows that the radioactive constants have not varied appreciably for at least 1,000 million years.

At any given time the rate of production of a particular lead isotope depends only on the disintegration constant and amount of the parental element then present. Thus the age of a mineral, t_m, can be readily calcu-

lated from each of the three ratios Pb^{206}/U, Pb^{207}/U and Pb^{208}/Th, where these symbols here represent the percentages of the parent elements and of the isotopes of radiogenic lead now present in the mineral under investigation. The respective equations for t_m, are:

$$t_m = 15.15 \times 10^9 \quad \log_{10} \quad (1 + 1.158 \; Pb^{206}/U) \text{ years}$$

$$t_m = 2.37 \times 10^9 \quad \log_{10} \quad (1 + 159.6 \; Pb^{207}/U) \text{ years}$$

$$t_m = 46.20 \times 10^9 \quad \log_{10} \quad (1 + 1.116 \; Pb^{208}/Th) \text{ years}$$

A fourth value for t_m can be found from the ratio Pb^{207}/Pb^{206}.

If a mineral has remained unaltered, then all four values for t_m should be in close agreement. In practice this rarely happens, because even in the freshest-looking mineral migrations of the critical elements are likely to have occurred. Fortunately, even if the three values for t_m based on Pb^{206}/U, Pb^{207}/U and Pb^{207}/Pb^{206} are widely different, the relations between them provide criteria for assessing the true age (fig. 2). If there has been leakage of radon (the gaseous member of the UI family), then the mineral is necessarily deficient in Pb^{206}; in this case the most probable age is given by Pb^{207}/U (see Wickman, 1942, and Holmes, 1947). If there has been loss of Pb or U or both, or gain of either or both, then the true age, or a close approximation to it, is given by Pb^{207}/Pb^{206}.

Although a great many radioactive minerals have been chemically analyzed, relatively few isotopic analyses of the lead have been made as yet. Prof. A. O. Nier, following up Aston's pioneer work, has been the most active and successful worker in this field. As an example of a fully investigated mineral, samarskite from Spinelli Quarry, Portland, Conn., may be taken. The mineral occurs in a pegmatite the geological age of which is not far from the end of the Devonian period.

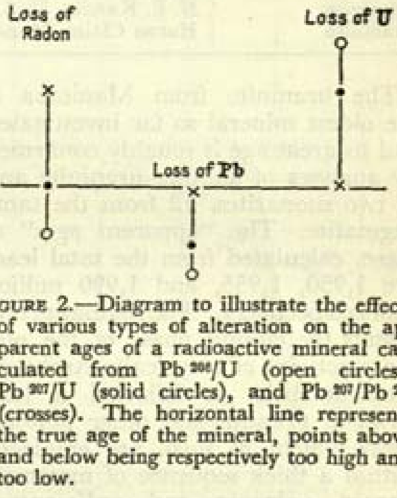

FIGURE 2.—Diagram to illustrate the effects of various types of alteration on the apparent ages of a radioactive mineral calculated from Pb^{206}/U (open circles), Pb^{207}/U (solid circles), and Pb^{207}/Pb^{206} (crosses). The horizontal line represents the true age of the mineral, points above and below being respectively too high and too low.

	Pb	*U*	*Th*	*"Apparent age" from total Pb (million years)*
Percentages (R. C. Wells)	0.314	6.91	3.05	295

Isotopic proportions (Nier *et aliter*)	Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
In total lead	0.167	100.00	7.60	21.30
In original lead	.167	3.04	2.61	6.35
In radiogenic lead		96.96	4.99	14.95
Percentages		.236	.012	.036
Age ratios	$\frac{Pb^{207}}{Pb^{206}}$	$\frac{Pb^{206}}{U}$	$\frac{Pb^{207}}{U}$	$\frac{Pb^{208}}{Th}$
	.0515	.03415	.00174	.0118
Values of t_m (million years)	256	255	254	266

Here the agreement is unusually good and it can be concluded that about 255 million years have elapsed since the close of the Devonian period.

In the following table some of the better-established dates are listed:

Mineral	*Locality*	*Geological Age*	*Probable age (millions of years)*
Pitchblende	Colorado	Beginning of Tertiary	58
Pitchblende	Bohemia	Late Carboniferous	215
Samarskite	Connecticut	End of Devonian	255
Cyrtolite	New York	End of Ordovician	350
Kolm	Sweden	Upper Cambrian	440
Pitchblende	Katanga, Belgian Congo	Pre-Cambrian	580
Uraninite	Morogoro, Tanganyika	Pre-Cambrian	590
Uraninite	Besner, Ontario	Pre-Cambrian	760
Bröggerite	Moss, S. Norway	Pre-Cambrian	860
Uraninite	Wilberforce, Ontario	Pre-Cambrian	1,035
Cleveite	Aust Agder, S. Norway	Pre-Cambrian	1,075
Pitchblende	Great Bear Lake, Canada	Pre-Cambrian	1,330
Uraninite	N. E. Karelia, U. S. S. R.	Pre-Cambrian	1,765
Uraninite	Huron Claim, Manitoba	Pre-Cambrian	1,985

The uraninite from Manitoba is the oldest mineral so far investigated and its great age is roughly confirmed by analyses of another uraninite and of two monazites, all from the same pegmatite. The "apparent ages" of these, calculated from the total lead, are 1,950, 1,955, and 1,990 million years respectively. The pegmatite represents the closing phase of the plutonic activity of a typically Archaean orogenic belt. It followed a long series of granitic and other plutonic rocks which, in turn, are emplaced within a thick sequence of metamorphosed volcanic and sedimentary rocks. The latter include still recognizable conglomerates, containing pebbles of preexisting granites and quartzites, which must therefore be well over 2,000 million years old. Since the earth must be older still, this figure can be regarded as a conservative minimum for its age.

To find a maximum for the age of the earth we may assume that when the earth began it was free from the lead isotope Pb^{207}, and that all the Pb^{207} now present in the common granitic rocks of the continental crust has since been generated from U^{235}. Granitic rocks contain on average about 20 p. p. m. of lead and 3.5 p. p. m. of U. The isotopic constitution of granitic lead has not yet been determined directly, but isotopic analyses of several samples of lead from galena and other lead ores of Tertiary age have been made by Nier and his coworkers. These ores represent concentrations of the granitic lead of some 25 million years ago, which is near enough to the present for our purpose. The average isotopic ambundances of Tertiary lead are

Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}	Total
1	18. 54	15. 55	38. 28	73. 37

corresponding in p. p. m. very nearly to

. 27	5. 1	4. 2	10. 4	20 p. p. m.

in the average granitic rocks of today. Inserting the values $Pb^{207}/U=4.2/3.5$ in the appropriate formula given on page 233, the time required for the generation of all the Pb^{207} is found to be 5,400 million years. The age of the earth is therefore somewhere between 2,000 and 5,400 million years.

Can we arrive at a closer estimate? I think we can, again by making use

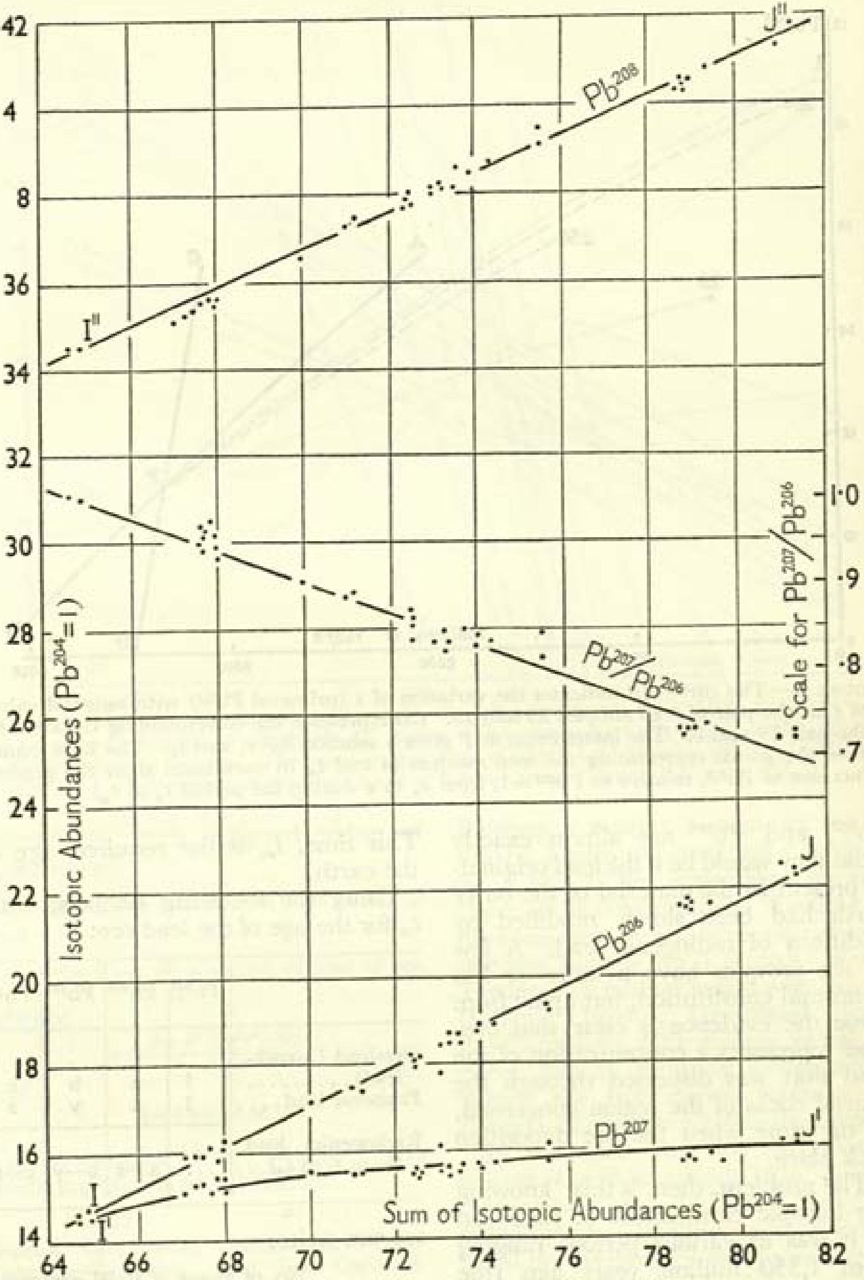

FIGURE 3.—To illustrate the relationships between the abundances of Pb^{206}, Pb^{207}, and Pb^{208} (relative to $Pb^{204}=1$) in lead samples prepared from common ores of lead.

of the invaluable data provided by Nier. He and his coworkers have determined the relative abundances of the isotopes in 25 samples of lead from common lead minerals of various geological ages. The results, graphically summarized in figure 3, reveal that the relationships between Pb^{206},

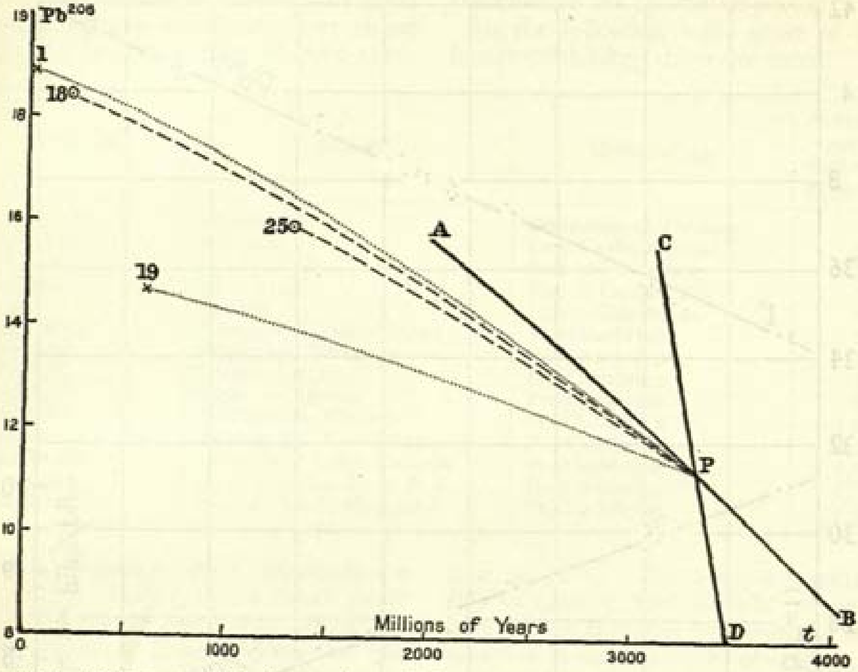

FIGURE 4.—The curve AB indicates the variation of x (primeval Pb^{206}) with assigned values of t for the pair of lead samples 25 and 18. CD represents the corresponding variation for the pair 19 and 1. The intersection at P gives a solution for x_o and t_o. The lines joining P to the points representing the lead samples (a and t_m in each case) show the gradual increase of Pb^{206}, relative to $Pb^{204}=1$, from x_o to a during the period t_o to t_m.

Pb^{207}, and Pb^{208} are almost exactly what they would be if the lead originally present in the material of the outer earth had been slowly modified by additions of radiogenic lead. A few of the samples have a more or less abnormal constitution, but apart from these the evidence is clear that ore-lead represents a concentration of the lead that was dispersed through the crustal rocks of the region concerned, at the time when the ore deposition took place.

The problem, then, is this: knowing the isotopic constitution of rock-lead as it was at various periods ranging from 1,330 million years ago (the Great Bear Lake sample) to 25 million years ago (the Tertiary samples), to find the relative abundances of Pb^{206} and Pb^{207} in the earth's primeval lead, and the time that has elapsed since that primeval lead began to be modified by radiogenic additions. This time, t_o, is the required age of the earth.

Using the following symbols, with t_m for the age of the lead ore:

	Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}
Ore-lead (=rock-lead)	1	a	b	c
Primeval lead	1	x	y	z
Radiogenic lead (from t_o to t_m)	.....	a—x	b—y	c—z

we can write:

$$\frac{b-y}{a-x}=r=\frac{\text{No. of atoms of } Pb^{207} \text{ generated from } t_o \text{ to } t_m}{\text{No. of atoms of } Pb^{206} \text{ generated from } t_o \text{ to } t_m}$$

From the expression on the right, r can be calculated (for each appropriate value of t_m) for various assigned values of t_o from 2,000 to 5,000 million

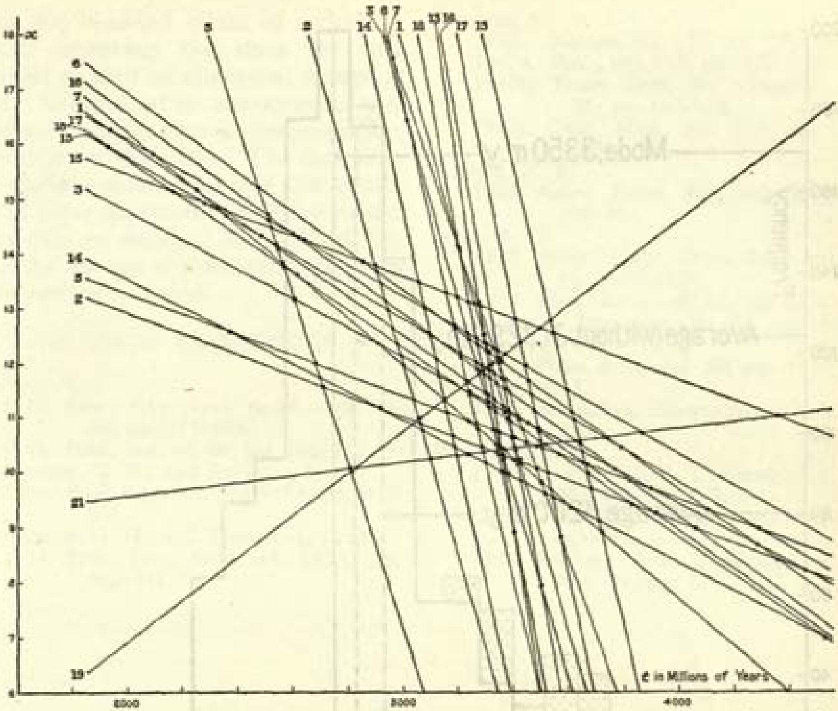

FIGURE 5.—Each of the curves numbered on the left corresponds (like *AB* in figure 4) to a pair of lead samples, of which No. 25 is one. The curves similarly based on No. 19 are numbered along the top. The numbers are those of Nier's lead samples as listed in Holmes (1946). Each intersection, marked by a dot, provides a solution for x_o and t_o.

years. For each assigned value of t_o we have:

$ar-xr=b-y$ for a sample of lead of age t_m

and

$a'r'-xr'=b'-y$ for a sample of lead of age t_m

whence

$$x=\frac{b-b'+a'r'-ar}{r'-r}$$

and

$$y=b+rx-ar.$$

Taking samples 25 and 18 (fig. 4) the following results are obtained:

No. 25	No. 18
Galena, Great Bear Lake Pre-Cambrian	Galena, North Carolina Late Carboniferous
$a=15.93$	$18.43=a$
$b=15.30$	$15.61=b$
$t_m=1{,}330$ million years	220 million years$=t_m$
$r=.23305$ when $t=2500$	$.16999=r'$
$x=14.11;\ y=14.87$	
$r=.30156$ when $t=3000$	$.22794=r'$
$x=12.40;\ y=14.24$	
$r=.39685$ when $t=3500$	$.30985=r'$
$x=10.59;\ y=13.18$	

Plotting x against t, a curve *AB* is drawn; a point representing a solution for x and t_o lies somewhere on this curve or its continuation. Dealing in the same way with another pair of lead samples, such as No. 1 (Galena, Peru, Tertiary, 25 million years) and No. 19 (Galena, Ivigtut, Greenland, Late Pre-Cambrian, 600 million years), a curve *CD* is similarly constructed. Where the two curves intersect at P, $x=11.22$ and $t_o=3{,}330$ million years.

In the same way we can plot y against t and construct two curves that intersect at $y=13.71$ and $t_o=3{,}330$ million years. The two pairs of curves based on the data for two pairs of lead samples thus yield a solution of the problem.

Obviously a great many solutions can be obtained by this method. Figure 5 illustrates the *xt* curves for pairs made up of No. 25 with each in turn of 14 younger lead samples, and for pairs made up of No. 19 with 11

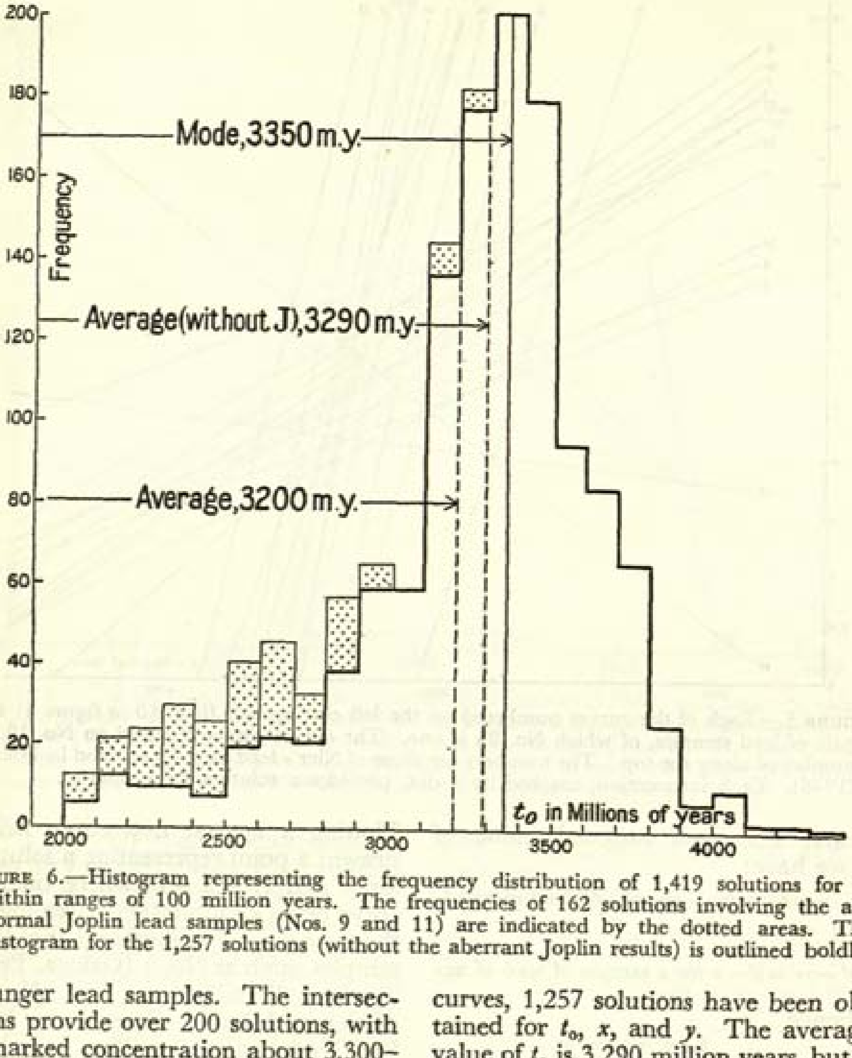

FIGURE 6.—Histogram representing the frequency distribution of 1,419 solutions for t_0 within ranges of 100 million years. The frequencies of 162 solutions involving the abnormal Joplin lead samples (Nos. 9 and 11) are indicated by the dotted areas. The histogram for the 1,257 solutions (without the aberrant Joplin results) is outlined boldly.

younger lead samples. The intersections provide over 200 solutions, with a marked concentration about 3,300–3,400 million years. Although there are naturally a few aberrant results, these are distributed more or less evenly about the mean, suggesting that no systematic or cumulative error is involved in the data.

Additional sets of curves can be constructed for pairs based on No. 23 (Cerussite, Broken Hill, N. S. W., 1,200 million years), No. 22 (Galena, same locality and age), and No. 21 (Galena, Quebec, 800 million years). From the intersections of all five sets of curves and of the corresponding *yt* curves, 1,257 solutions have been obtained for t_0, x, and y. The average value of t_0 is 3,290 million years, but a histogram of the t_0 values (fig. 6) reveals a well-marked mode at 3,350 million years, which is found to be somewhat better than the average value when tested by a least-squares method (Holmes, 1947a, p. 127). The spread of the results is comparable with that of figure 5, and is not surprising in view of the many possibilities of error. Careful consideration of the latter suggests that on the whole they tend to counterbalance rather than to become cumulative. The dotted frequencies on the left of figure 6 illus-

trate the lopsided effect of including results involving the data for two samples of lead of abnormal constitution. Certain other abnormal leads, however, would give a concentration of results on the right. The fact that the modal solution remains independent of these aberrant results favors the hope that an estimate of 3,350 million years for the age of the earth is unlikely to be seriously wrong.

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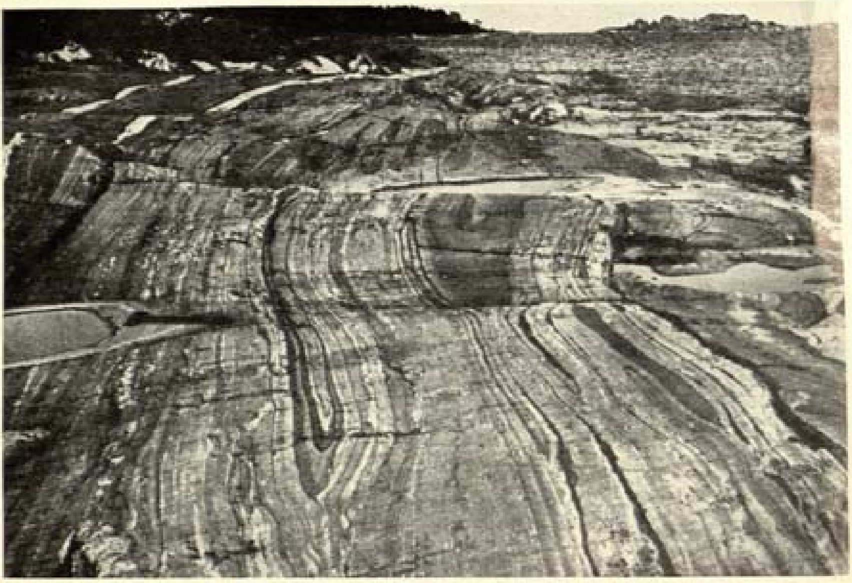
1. Upper old red sandstone strata (age about 280 million years) resting unconformably on vertical Silurian rocks (about 320 million years) at Siccar Point, Cockburnspath, Berwickshire.

Photograph courtesy H. M. Geological Survey, by permission of the Director.

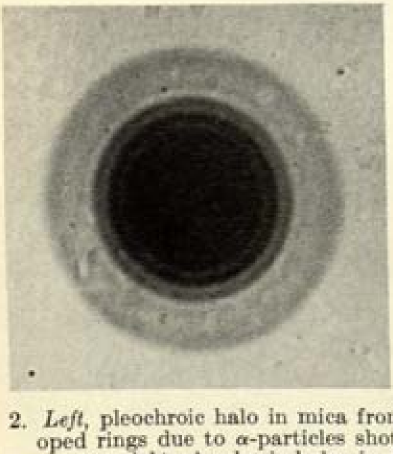
2. Carboniferous limestone (about 240 million years) resting unconformably on inclined Silurian slates (about 320 million years) at Arco Wood Quarry, 4 miles north of Settle, Yorkshire.

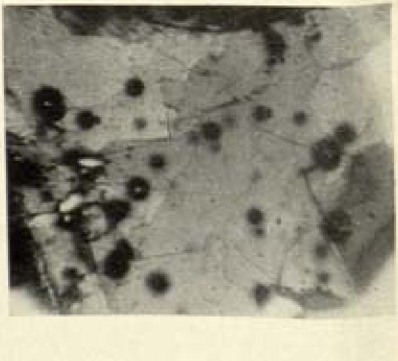
Photograph by Prof. S. H. Reynolds.



1. Wave-swept surface of folded rocks, metamorphosed and partly granitized, representing the worn-down roots of a pre-Cambrian orogenic belt (about 1,060 million years), at Borga, south coast of Finland.

Photograph by Prof. C. E. Wegmann.





2. *Left*, pleochroic halo in mica from Murray Bay, Quebec, showing well-developed rings due to α-particles shot out from a uranium-bearing crystal at the center; *right*, pleochroic halos in a flake of brown mica from a Pre-Cambrian granite (about 1,030 million years) from Ontario, Canada.

Photomicrographs by Prof. G. H. Henderson.

Petroleum Resources of North America[1]

By A. I. Levorsen, *School of Mineral Sciences, Stanford University*

This evening I would like to talk to you about our petroleum resources. By "our" I mean North American, and by "petroleum" I mean oil and gas occurring naturally. Petroleum is only one of the mineral substances in which the public is vitally concerned as to supply, but it is the one which probably uses the most geology and geologists, and it happens to be the one in which my experience lies.

To begin with, petroleum is important. It is necessary in peace and essential in war. The often repeated statement of Lord Curzon of the British War Cabinet that in War I "The allies were floated to victory on a flood oil" applied equally well to World War II when over 60 percent of the total tonnage—men, munitions, food, and supplies—which was shipped overseas consisted of petroleum products. It is no wonder that a committee of the United States Senate, after a thorough study and many hearings on the problems of the petroleum industry, made a report containing the following significant statement: "It is now clear that no nation which lacks a sure supply of liquid fuel can hope to maintain a position of leadership among the peoples of the world." This same committee also stated, in regard to the role American oil played in the recent war, "In the final analysis, the reserves within our borders can more likely than not constitute the citadel of our defense."

Our current use of oil is the greatest in our history—even greater than at any time during the recent war—and much greater than that of any other people. Americans have an annual per capita consumption of 420 gallons as compared with 42 gallons for Great Britain and 14 for all other nations combined. The rate of our use has been accelerating, and all information indicates that it will continue to do so indefinitely. On the other hand, our rate of production already is running so close to capacity that it gives legitimate alarm about our ability to continue to supply adequate amounts of petroleum during the decades ahead. Not only is it necessary to produce enough for our normal expanding peacetime needs, but we must likewise be prepared constantly for any emergency which would again require a sudden expansion of our production. Our future supplies of petroleum are consequently of great national concern.

We often hear the statement made that the discovery of each new oil field means one less in the ultimate finite number of fields. This is correct but rather meaningless. We do our national planning on what we *think* the ultimate quantity is in terms of our needs rather than on any fixed and finite number. Ideas about the future discoveries are constantly changing, depending on developments and viewpoints, and varying from extreme pes-

[1] Presidential address of retiring president of The Geological Society of America, originally entitled "Our Petroleum Resources." Reprinted, with change of title, by permission from the Bulletin of The Geological Society of America, vol. 59, April 1948.

simism to extreme optimism. For example, a representative of the State Department recently testifying before a committee of the United States Senate stated with somewhat of a psychic finality that the reason why we have not found more new oil is "Because the oil is not there to be found." Far more to the point, it seems to me, would be to reason that because of the recent discovery at the Leduc, or South Edmonton field, in Alberta, for example, we have opened our minds to vast new possibilities in western Canada. Not one pool less, but rather many pools *more* will result from this one discovery.

The great question facing us now is how long can we continue to replace our annual consumption of petroleum through discoveries of new oil and gas fields? When must we look to other sources—either substitutes or imports from other continents? If we have no more oil to discover, then it is not too soon to start working on some alternate solution. Our needs are great and are constantly increasing. The answer to this problem of adequate supply of petroleum may well become critical to our very existence.

What help can geology give on this problem? Because petroleum is found in the rocks and the earth, and because we, as geologists, represent the science which is concerned with rocks and the earth, we are, whether we wish it or not, faced with a great public responsibility. We are expected to keep the people of North America advised on the prospects of adequate future discoveries of petroleum on this continent. Geology, of all the sciences, offers the key to the evaluation of the ultimate extent of our mineral resources. It is my contention that, as geologists, the problem is squarely in our laps, and that our highest social purpose—the finding of new mineral deposits—is being put to a test as never before.

During times of world peace, the petroleum resources of the world are ample to take care of all requirements for generations to come. Petroleum can be moved readily from one continent to another, and the importing of petroleum is a very simple and obvious answer to the lack of it in any part of the world. However, as tensions multiply and international relations become strained, each nation must be prepared to depend entirely on its own resources—that is, those resources which it can protect. In our case, once we on this continent become dependent on a foreign or an oceanborne supply, not only of petroleum but of every other mineral substance as well, our world position is weakened and our defense and self-preservation become proportionately vulnerable.

If we cannot import petroleum with safety to our future, what are the alternatives? The first is to manufacture substitute fuels from our great reserves of coal, oil shales, and tar sands. This seems to offer a solution which is safe, ample in quantity of raw material, and which is technically possible now. The cost is great, however, compared to naturally occurring liquid fuels, and there are many problems which remain to be worked out if such methods are called upon to supply anything more than nominal amounts of petroleum products. But, because there is such a vast amount of hydrocarbon material contained in these deposits, nothing should be left undone which would help make it available for use.

The second alternative is very simple to state but is difficult to achieve. It is to increase oil-field discovery within the continental borders of North America to keep pace with the rising needs. It is this solution that I would like to discuss with you more fully.

If we are to expand our discovery rate, the problem naturally falls into two parts. First, is there enough new oil to be discovered? and second, How is it to be found? The finding of it is readily answered—more drilling. Oil and gas are found in only one way, that is by the drilling of wells. The number of dry holes in some of the productive regions of the United States

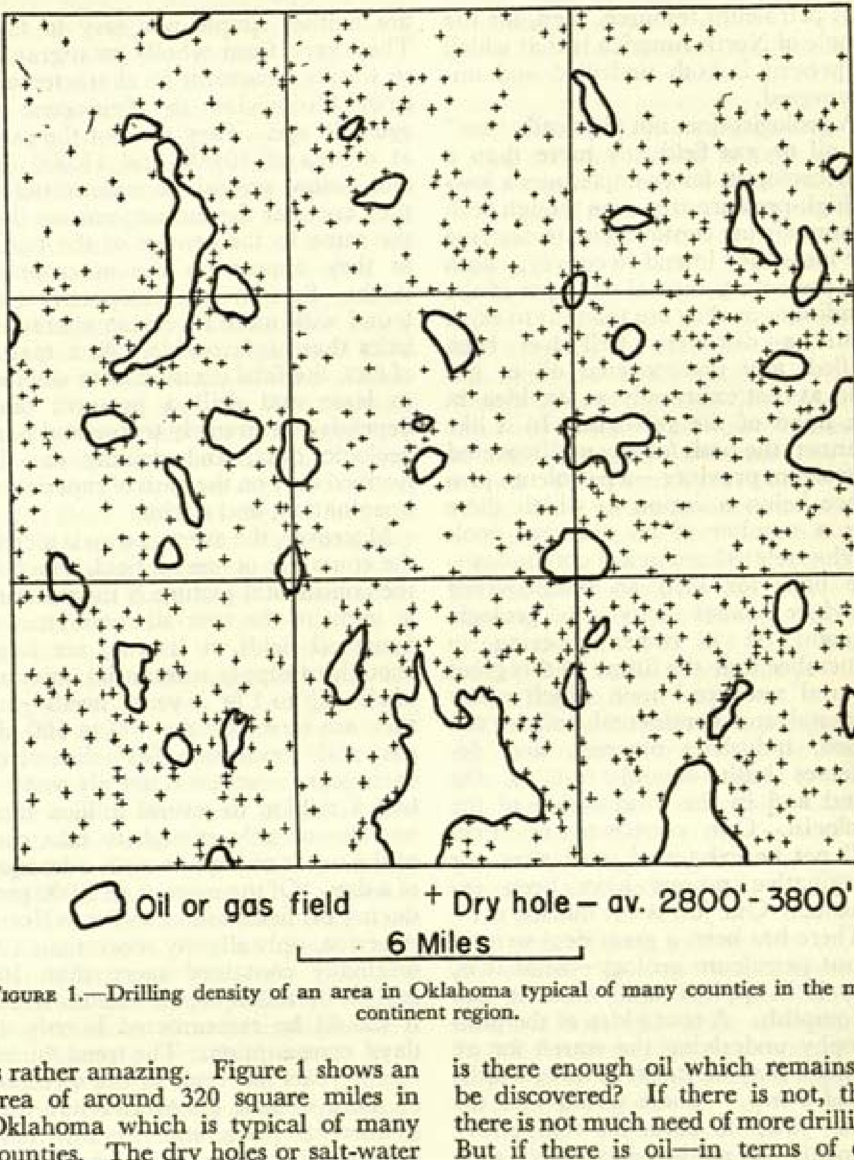


FIGURE 1.—Drilling density of an area in Oklahoma typical of many counties in the mid-continent region.

is rather amazing. Figure 1 shows an area of around 320 square miles in Oklahoma which is typical of many counties. The dry holes or salt-water wells—each representing a geologic column—average less than a mile apart. One might conclude from this, no wonder they find oil! When we think of the plains region of Canada with test wells 50 miles or more apart, the immensity of the drilling program necessary to locate all the oil fields becomes apparent.

We then come back to the first part, which is the crux of the problem—is there enough oil which remains to be discovered? If there is not, then there is not much need of more drilling. But if there is oil—in terms of our national needs—remaining to be found then we should be on with the business of locating it. The presently known recoverable oil reserves of 21 billion barrels or more—about 12 times the annual consumption—is merely a working stock. Much of the oil we are using today was unknown 20 years ago, and likewise the oil we will use 20 years hence is in a large part still undiscovered. The really impor-

tant petroleum resource, then, for the people of North America is that which at present is both undrilled and undiscovered.

A geologist does not physically "see" an oil or gas field any more than a meteorologist, for example, sees a low- or high-pressure area even though both commonly use contour lines to describe the ideas they intend to convey. Both are presenting mental concepts of the conditions as they are thought to exist. Until a discovery well has been drilled, any undiscovered oil or gas field at best exists only as an idea in the mind of the geologist. In a like manner, the basis for any undiscovered petroleum province—a petroleum province being a region in which there are a number of oil and gas pools having related geological conditions—the basis for such an undiscovered province exists only in geologic thought. It is rather sobering to remember that the future of this great natural resource—upon which many national and continental policies are based, industries planned, and dedefenses built—should rest in the mind and in the imagination of the geologist. Our petroleum resources will not be exhausted until after our imaginative powers have been exhausted. Our job is cut out for us!

There has been a great deal written about petroleum geology—what it is, how it is applied and what it can accomplish. A crude idea of the phillosophy underlying the search for an oil pool, may be stated in three words: "*Find a trap.*" Some would add the word "*first,*" to cover the competitive element. As might be expected, such a definition suffers from over-simplification, but it does contain the underlying objective of nearly all petroleum-exploration geology and geophysics. Prejudices against fresh water, red sediments, continental beds, high-carbon ratios, lack of source rocks, closeness to the mountains, and lack of sands fade rapidly in the face of a good trap.

It so happens, however, that traps are neither simple nor easy to find. They vary from wholly stratigraphic to wholly structural in character and from Ordovician to Pleistocene in geologic age. They are not the same at depths of 10,000 and 15,000 feet and below several unconformities as they are near the surface; nor are they the same in the centers of the basins as they appear on the outcropping flanks. Seldom is a prospective trap found with more favorable characteristics than unfavorable. As a matter of fact, the final decision as to whether to lease and drill a prospect often depends on extremely tenous and hazy geologic data, and drilling can be justified only on the basis of experience, imagination, and daring.

Moreover, the average trap is merely the container of one oil field, which in the continental picture is insignificant in terms of the over-all requirements. Some oil fields, it is true, are large enough to supply substantial amounts of oil—up to 1 or 2 years' needs—but they are rare. Of the 400 to 500 oil, gas, and condensate fields discovered each year, most are relatively small—half a million to several million total barrels—or only enough to take care of the needs of days or even a fraction of a day. Of the more than 3,000 producing oil fields found so far in North America, only slightly more than 100 originally contained more than 100 million barrels of oil, an amount which it should be remembered is only 20 days' consumption. The trend during recent years has been in the direction of more annual discoveries but with smaller-size pools, and it is this trend of small discoveries which gives alarm to many persons. To solve the problem effectively, our thinking must be in terms of provinces.

The presently active provinces such as the Gulf Coast, West Texas, the San Joaquin Valley, the mid-continent States, and the Rocky Mountain region can all be expected to continue to provide new oil and gas fields for many years to come. The prospects for further discovery in these areas are

by no means exhausted, but to meet the ever-increasing demands new areas must be added to them.

When in geologic thought we proceed outward from these established areas of production, however, we come into more and more speculative regions which require increasing amounts of geologic imagination to visualize their potentialities in terms of important future supplies. Some examples of these areas or prospective provinces are the Anadarko Basin; the Continental Shelf; the coastal plains of Mexico; the interior plains of western Canada; Florida and the Southeastern States; New Brunswick and other Maritime Provinces; the Atlantic Coastal Plain; the Great Basin region; the overthrust fault belts and the sediments of Cambrian age. Valid objections, both geologic and economic, can be found to each of these areas which either overbalance the favorable factors or are overbalanced by them depending on who makes the appraisal, for what purpose, and when. There is nothing new in such a statement as every individual prospect, even in the old established provinces, goes through the same sort of reasoning in the normal competitive operation of the petroleum industry. The test well is finally drilled when, in the mind of someone, the favorable factors overbalance the unfavorable. Countless pools have been discovered when the majority, orthodox geologic opinion rated the prospects low, or even negligible and the discovery well had but a small minority support.

The characteristics of provinces parallel those of individual oil fields in many respects, and the single oil or gas pool is often a "hand specimen" of the province insofar as its geologic history is concerned. Experience has shown that every oil field is unique in that it has its own stratigraphic and structural development, and the same uniqueness is true of a province. Therefore, in a new province, we should not expect to duplicate the geologic history found in the proven provinces. Any evaluation of prospective producing regions should depend rather on the objective application of principles to the observed geologic conditions of the area being considered.

Reduced to their simplest terms, the geologic factors which favor a region as a potential petroleum province are: (1) sediments, preferably but not necessarily marine, variable, and unmetamorphosed—generally the more the better; (2) evidences of oil and gas, either from surface seepages or showings in wells; (3) unconformities—also the more the better; and (4) up-dip wedge belts of permeability resulting from any cause. These factors may be termed common denominators of known petroleum provinces, and, while their presence does not assure commercial production in a new region, yet the better and stronger these factors are developed, the better the chances for such production. Once a petroleum province has been established, there remains only the problem of finding the local traps.

The geologic merit of a prospective region is often tempered by the excessive drilling depths necessary to reach the productive formations. During recent years, the average depth of exploratory drilling has steadily increased, and today wells 12,000 to 15,000 feet in depth are common. The deepest hole to date was drilled last summer in western Oklahoma to a depth of 17,823 feet. It is therefore assumed that test wells as much as 20,000 feet in depth may be considered as practical in the petroleum exploration of the future.

Another important factor which enters into the consideration of a prospective region is its distance from the market. Our petroleum demand is strong enough that it can be expected to reach for supply anywhere on this continent either through pipe lines or ocean transport, provided the supply is large enough to justify the expense. While distance from market is commonly thought of in terms of miles, equally significant are the hurdles

which are placed at national boundaries. Our geographic position as a compact continent and the geologic boundaries which determine where our petroleum resources are to be found antedate national boundaries and are far more fundamental to our future welfare than are any man-made rules as to traffic between our countries. It seems to me that we in North America are extremely short-sighted in thinking of ourselves as separate and independent countries when we are so interdependent in terms of all of our natural resources. We on this continent are going to stand or fall together, and there should be no place for trade barriers between our peoples. It is for these reasons that, in appraising our petroleum resources, the prospective areas should be considered throughout all North America, irrespective of the country within which they happen to occur or the distance in miles from the market.

Figure 2.—Reference map of North America showing the three prospective types of areas selected for analysis.

Three of the prospective areas have been selected as typical of the kind and scale of geologic thought and imagination which it seems is necessary to analyze intelligently our undiscovered petroleum resources. They are presented in the discussion which

follows. The data used are all taken from geologic articles and publications available to everyone, much of it in the publications of our Geological Society. It is the purpose here to give some indication of the enormous volumes of rocks favorable to petroleum production but which are as yet essentially unexplored. Some of these areas and ideas are highly speculative at this time, but experience has shown over and over again that every producing area, whether an individual field or a great province, was at one time in a similar speculative position.

The areas selected are shown on the North American base map, figure 2. They are: (1) the overthrust fault belts; (2) the plains regions of western Canada and Alaska and of eastern Mexico and Guatemala; and (3) the wedge out of Lower Cretaceous and Jurassic sediments in the Southeastern States.

(1) *Overthrust fault belts.*—More than 2,500 linear miles from 5 to 100 miles wide are shown on the base map in which older rocks are thrust over younger rocks and in which the geology is so complicated as to make it extremely difficult to map and understand. Interpretation of geophysical measurements in these fault areas is generally impossible. The correct knowledge of the geology appears to lie in better and more accurate surface mapping coupled with careful records of deep wells. Probably of equal importance is the need for geologists to learn more of the nature and mechanics of faulting.

Yet, within these overthrust belts, evidence of petroleum has been found at many places, and several oil fields discovered. One of these belts extends from British Columbia and Alberta south across western Montana and Wyoming and into Utah and Nevada. The Turner Valley pool of Alberta (fig. 3) is located in it. Another belt is located in the western Ouachita Mountains of Oklahoma and probably extends southwest across Texas. The South Mountain pool (fig. 4) is one of several examples of oil pools in the Ventura region of California characterized by thrust faulting. The third belt is in the Appalachian Mountains extending from New York into Alabama where it passes under the overlapping Cretaceous and Tertiary rocks. The recently discovered Rose Hill pool (fig. 5) in Virginia occurs in this belt. Apparently thrust faulting and the sort of deformation which occurs in these belts are not detrimental to the occurrence of petroleum.

One factor which makes these belts favorable for petroleum accumulation is the fact that they are generally located over areas in which the sediments increase rapidly in thickness, often thickening at a rate of hundreds of feet to the mile. Wherever sediments thicken, we may expect to find wedge belts of porosity and permeability, a phenomenon common to many proven oil-bearing provinces. Since the belts of expanding sediments antedate the faulting, they thus provide a regional trap before the faulting occurred. In fact, they may have also localized the thrusting over the initial dips which prevailed.

The Choctaw and related overthrust faults in the western part of the Ouachita Mountains of Oklahoma (fig. 6) deserve special attention as one example of the scale of trap we may expect to find in these overthrust belts. Here the Ouachita facies of Paleozoic age are thrust northwest out and over the buried Arbuckle rock facies along a front 50 to 100 miles in length. The surface maps of this part of Oklahoma show the faulted area as separating the Lehigh Basin to the northwest from the Prairie Hollow syncline to the southeast, in each of which the rocks are dropped down nearly 2 miles. The map and cross sections recently published by Hendricks of the United States Geological Survey are the basis of the section (fig. 7). Below the Choctaw overthrust fault, a large anticline is shown in the older Paleozoic formations of the Arbuckle facies,

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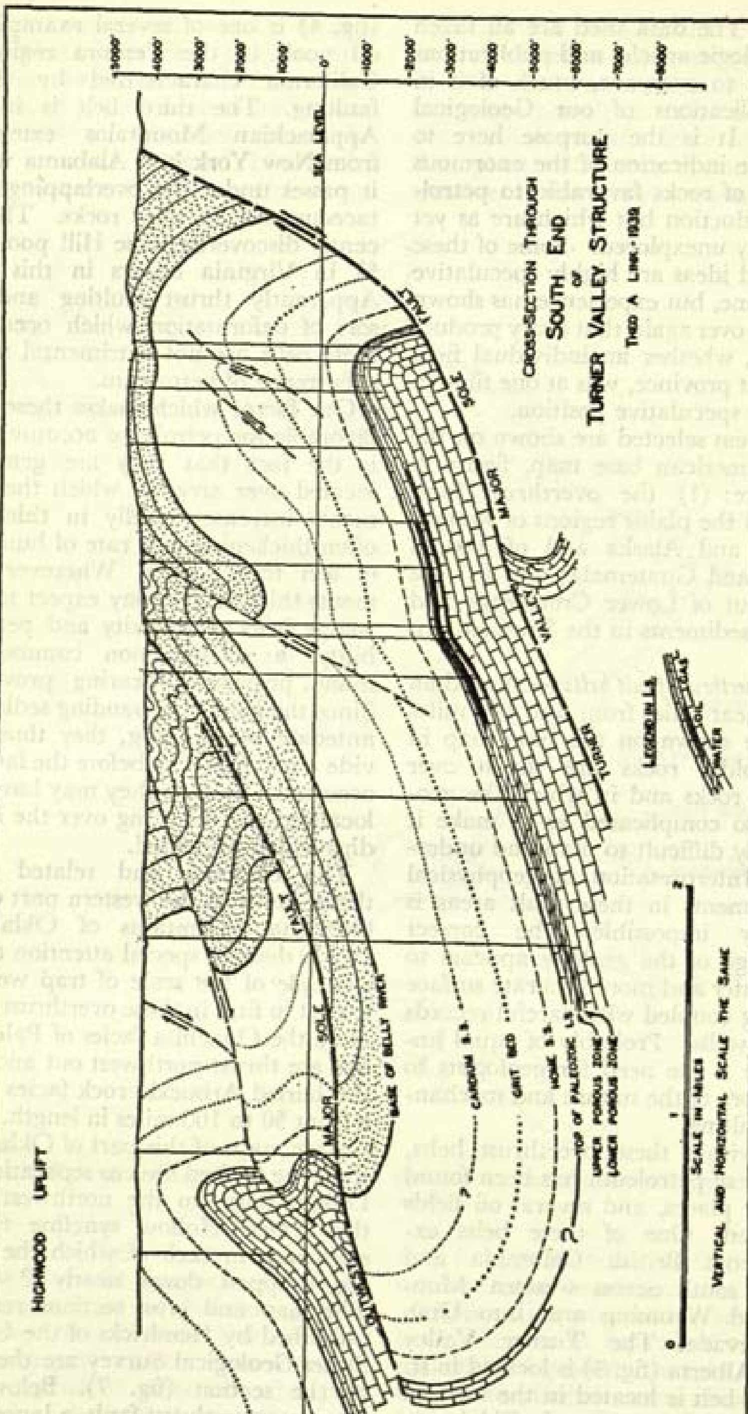

FIGURE 3.—Section through the Turner Valley field in Alberta, Canada. (After Link.)

including the Hunton limestone, the Viola limestone, the Simpson sands, and the Arbuckle limestone, all of which are richly productive in the important Oklahoma oil fields 25 to 75 miles to the west and northwest. Moreover, above the area of this fold and within the faulted overthrust rocks are found a large number of oil belief that, if productive, it will be large—in other words, here is one area possibly containing an unexplored trap a dozen times as large as the Oklahoma City field!

The recent discovery of oil at Rose Hill in Virginia (fig. 5) located in the overthrust Appalachian region directs attention to a large area of complex

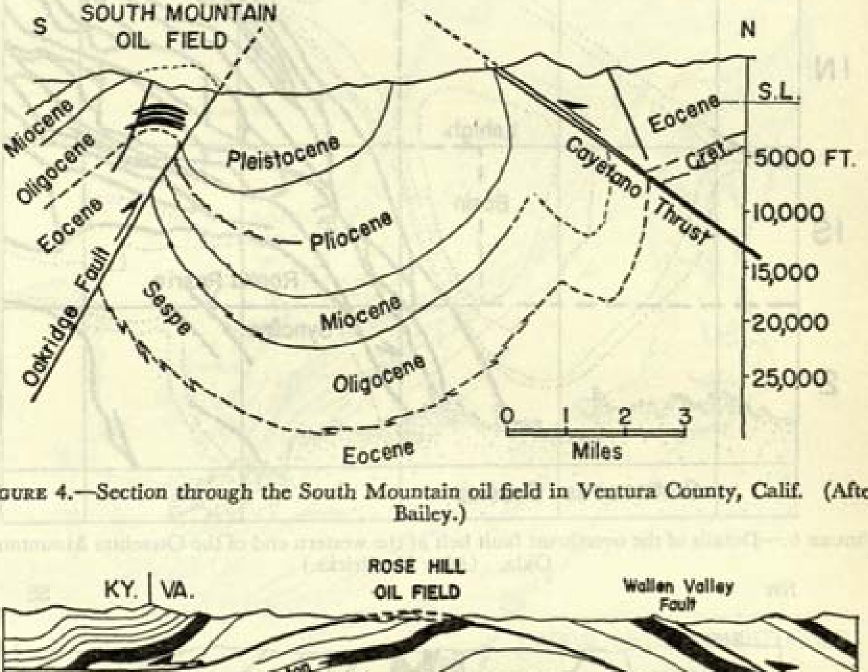

FIGURE 4.—Section through the South Mountain oil field in Ventura County, Calif. (After Bailey.)

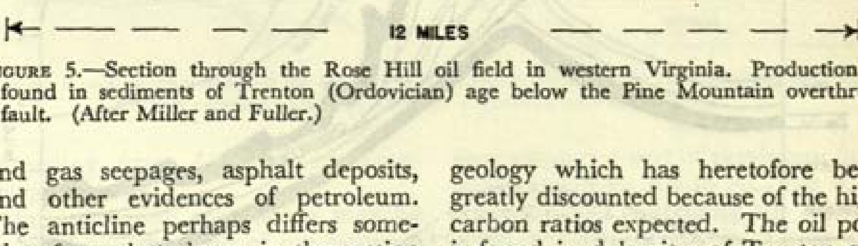

FIGURE 5.—Section through the Rose Hill oil field in western Virginia. Production is found in sediments of Trenton (Ordovician) age below the Pine Mountain overthrust fault. (After Miller and Fuller.)

and gas seepages, asphalt deposits, and other evidences of petroleum. The anticline perhaps differs somewhat from that shown in the section due to the rapid thickening of the Pennsylvanian sediments toward the southeast, but even so there is undoubtedly a fold of some sort in the early rocks at this locality. It is of a size and proportion to justify the geology which has heretofore been greatly discounted because of the high carbon ratios expected. The oil pool is found in dolomites of Trenton age where overridden by early Ordovician and Cambrian rocks. In addition to the oil at Rose Hill, gas has been found in the overthrust belt at Early and Bristol, both in Virginia. Source rocks consequently have been demon-

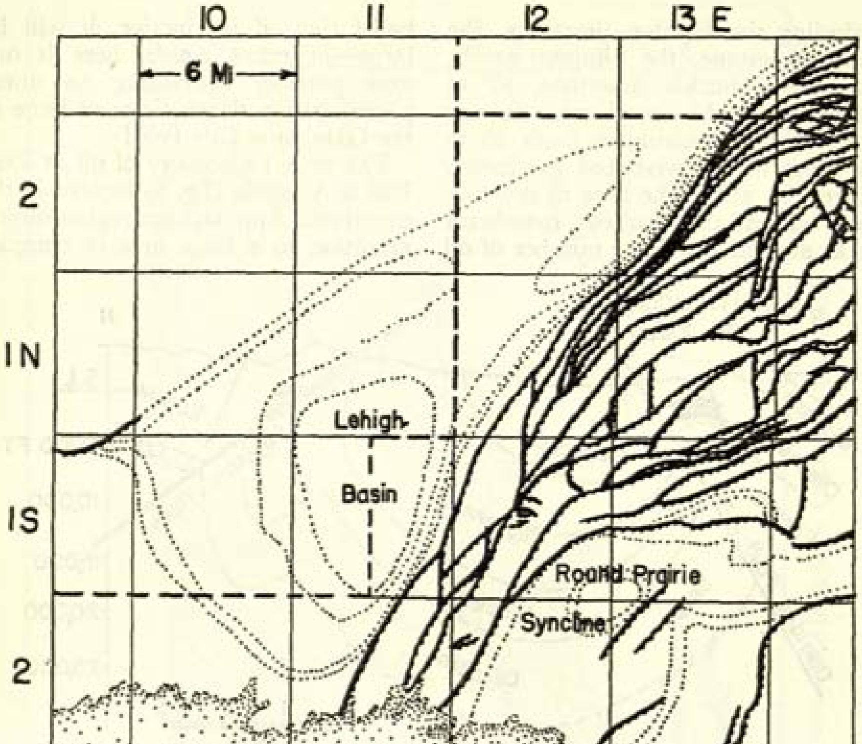

FIGURE 6.—Details of the overthrust fault belt at the western end of the Ouachita Mountains, Okla. (After Hendricks.)

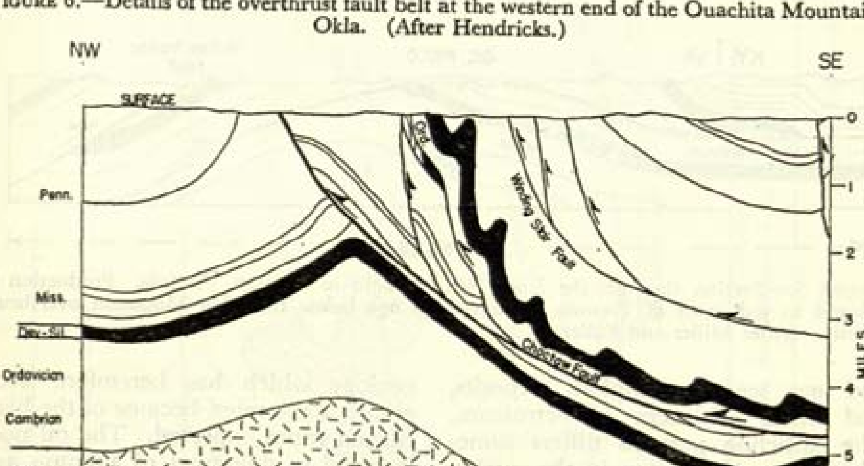

FIGURE 7.—Section across western end of Ouachita Mountains overthrust fault belt extending from Lehigh Basin to Round Prairie syncline. (After Hendricks.)

strated. Folds of all degrees of intensity, coupled with unconformities, facies changes, rapid eastward thickening of all rocks in the geologic column from Cambrian to Pennsylvanian in age, and all sliced with great numbers of low-angle faults assure an almost unlimited number of traps lineation is more nearly north and south and passes under the southwest-northeast trend of the later overthrusting. Moreover, the number of faults and their intensity increase from northeast to southwest until the belt passes under the Cretaceous and Tertiary overlap in Alabama. The pat-

FIGURE 8.—Reference map of the eastern United States showing the Appalachian overthrust belt crossing obliquely an older regional pattern of folding.

extending from Alabama to Pennsylvania.

An interesting speculation may be be made on the basis of the evidence indicated on the geologic map, shown in figure 8. It is rather evident from this map that the fault belt crosses obliquely an older pattern of folding shown by the anticlinal trends and the regional strike of the rocks. This older tern suggests a sort of pendulum fault movement from AB to AC, the rocks from the east overriding the western rocks a progressively increasing distance from north to south.

The underlying western rocks are known oil and gas producers and may extend far to the east below the soles of the overthrust series. Isopach and paleogeologic maps offer the means of

proving the extent of the overthrusting. Pressure for more oil and gas discovery will provide the incentive for the drilling of the deep holes necessary to test the formations below the faults.

(2) *Plains of Alaska and western Canada, and eastern Mexico and Guatemala.*—These two areas, which appear to be the northern and southern extremities of the western plains regions of the United States, much of which has been so productive of oil and gas, cover an area of over a million square miles in Alaska, Canada, and northern United States, and 300,000 square miles in Mexico and Guatemala.

They are considered together because they have many common characteristics significant in the geology of petroleum. Both contain large volumes of sediments, Both also contain numerous and widespread evidences of petroleum in the form of seepages, asphalt and tar deposits, as well as proven oil and gas fields. There can be no question as to abundant source rocks.

The geologic section in the western Canadian plains contains five regional unconformities, and the Mexican section contains as many or more. One of the important functions of unconformities is to mark the truncation of porous formations below the unconformity. Likewise, the overlapping formations above the plane of the unconformity often contain porous members or lenses. Such stratigraphic phenomena close to unconformites account for a substantial percentage of the world's oil fields. Probably of equal importance to the petroleum geologist is the masking effect of unconformities—they conceal the underlying geology. The presence of an unconformity in the geologic section is notice to the exploration geologist that a new and unknown set of conditions, structural as well as stratigraphic, may be expected to exist below. In many provinces, drilling through unconformities has revealed new and unsuspected deeper formations which caused both geological and geophysical upsets.

In addition to the unconformities, sections of rocks in both areas show numerous changes in facies; lateral variations in porosity, limestone reefs, and interbedded continental and marine sediments. The combination of the unconformities and changes in facies gives to both areas innumerable possibilities for stratigraphic traps of every conceivable variety. Local deformation in an area characterized by such stratigraphic variations need not be strong. Gentle folds, structural terraces, and other minor structures can easily become effective traps for large oil pools especially when combined with lateral changes in porosity and permeability.

The average thickness of sediments in these two areas which might carry petroleum is on the order of 2 miles, which means a total volume of sediments of over 2½ million cubic miles—a truly large volume of prospective material which is today essentially unexplored! It is inconceivable that such a large volume of rocks, in which every prerequisite of a petroleum province is richly developed, should not be the site of hundreds upon hundreds of oil fields yet to be discovered. Deposits such as the Athabaska oil sands of Canada or the Golden Lane and Poza Rica fields in Mexico give a measure of the possible size of some of these undiscovered fields. Not until thousands of additional test wells have been drilled throughout both regions can we say that the exploration of these areas has been completed.

(3) *Southeastern United States.*—The dome structure in contours might be called the symbol of the petroleum geologist of the 1920's—it was practically the sole objective in his search for traps. While a dome structure is still as desirable a guide to an oil pool as ever, it is gradually being learned that stratigraphic variations are probably equally as important as folding and faulting in the formation of traps. One of the greatest oil fields in the world, the East Texas field, has a cross section which is symbolic of the chang-

ing emphasis (fig. 9) and which is repeated in many forms in countless oil and gas fields. Whether it is an oil filed in the small sand lens in Kansas or Alberta, the porous limestone reefs of West Texas or Mexico, the dolomite grading into limestone in Indiana and Ohio, the rapid lateral change of a sand to shale in California, or the wedges bounded by unconformities as East Texas, the principle is the same—an up-dip wedging out of porosity and permeability in the reservoir rock. This principle applies not only to individual fields, but also to many provinces. Such a province may be looked upon as a large-scale version of the up-dip wedge of permeability in which the oil and gas are first accumulated in the regional trap and later localized into pools by minor deformations and local stratigraphic variations. Whether the stratigraphic variation is on the scale of either a single pool or a province, it has the advantage of being the earliest trap in the geologic life of the reservoir rock, and consequently having had more time in which to accumulate oil and gas. As a consequence, any up-dip wedge edge of permeability in a potentially producing formation is significant.

One of the largest of these phenomena, which as yet has not been tested, occurs in the southeastern States of Mississippi, Alabama, and Florida where the wedge edge of the Lower Cretaceous and Jurassic rocks crosses first the southwest-plunging Appalachian arch and again the Florida uplift (fig. 10). These two rock series occur below the Upper Cretaceous in East Texas, southern Arkansas, and northern Louisiana and contain the reservoir rocks of more than 125 oil and gas fields (fig. 11). This wedge is expanding at a rate of 100 feet per mile down the dip and somewhere in Mississippi and Alabama it crosses the southwestern extension of the Appalachian arch setting up a potential trap area of thousands of square miles. Farther southeast in Florida it crosses the southern extension of the Florida arch where production has already been found in Cretaceous rocks (fig. 12). Here again there is a potential trap area of thousands of square miles in a group of rocks which have produced fields like Smackover, Rodessa, and Schuler along the same trend. Drilling will be deep, it is true, probably beyond 15,000 feet and even as deep as 20,000 feet. No one can even guess in advance of drilling what structure, stratigraphic sequences, or

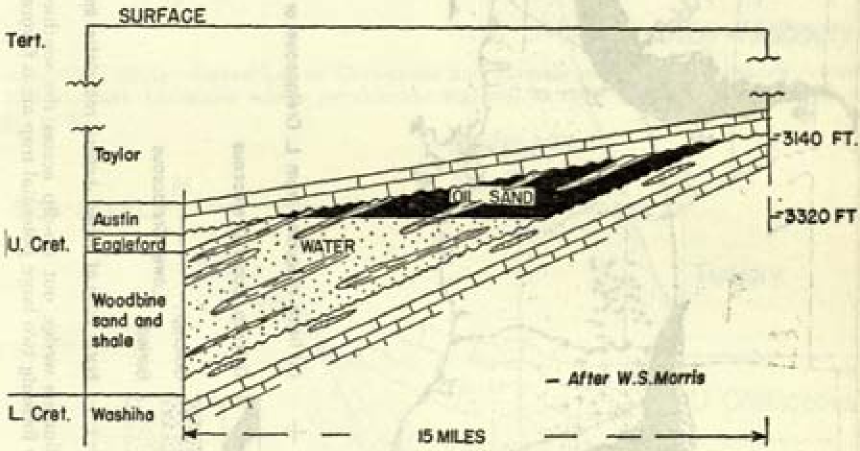

FIGURE 9.—Generalized west-east cross section of the East Texas oil field. The wedge shape of the producing formation is repeated in various ways in many oil and gas fields.

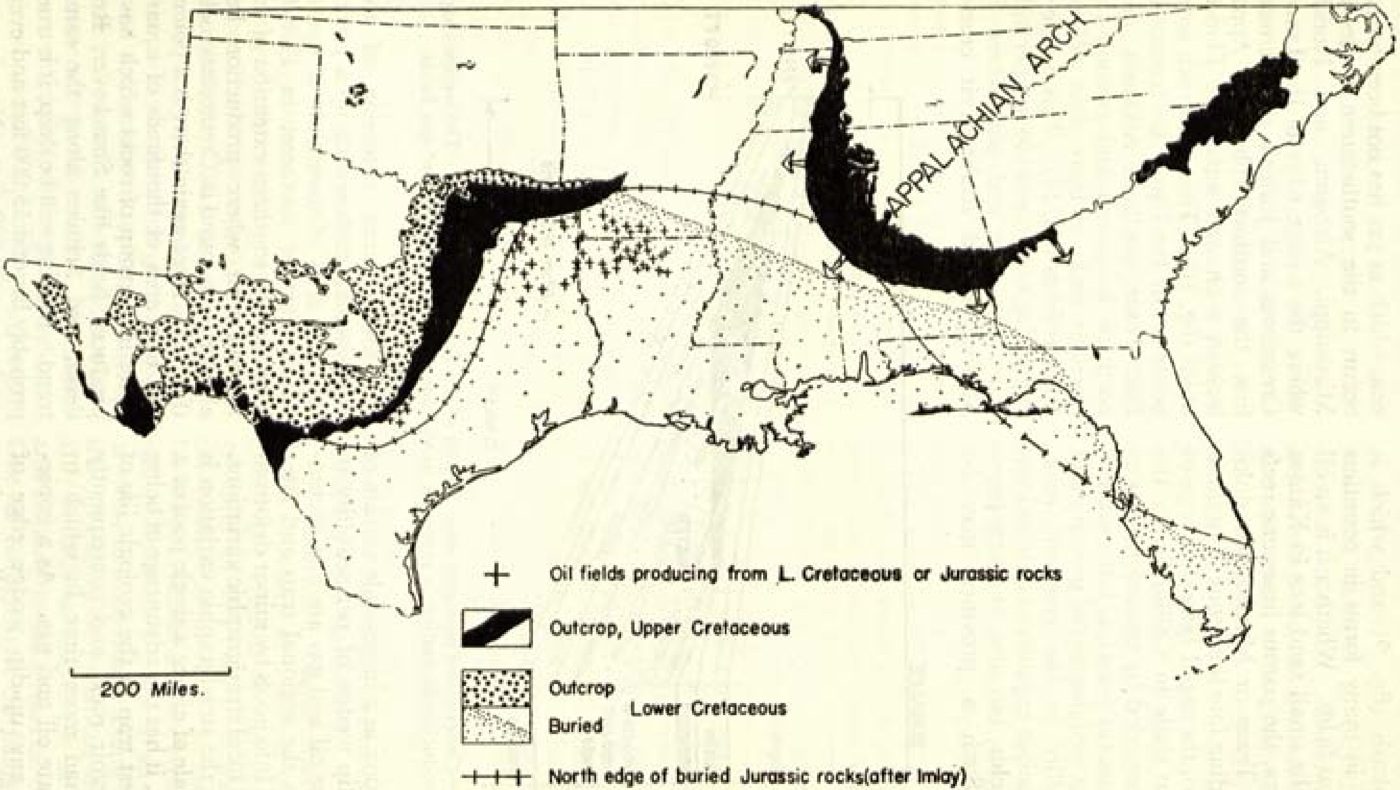

FIGURE 10.—Lower Cretaceous and Jurassic sediments wedge out up-dip across the southwestern-plunging Appalachian Arch and again across the Florida Uplift, thereby forming two large potential trap areas favorable to petroleum accumulation.

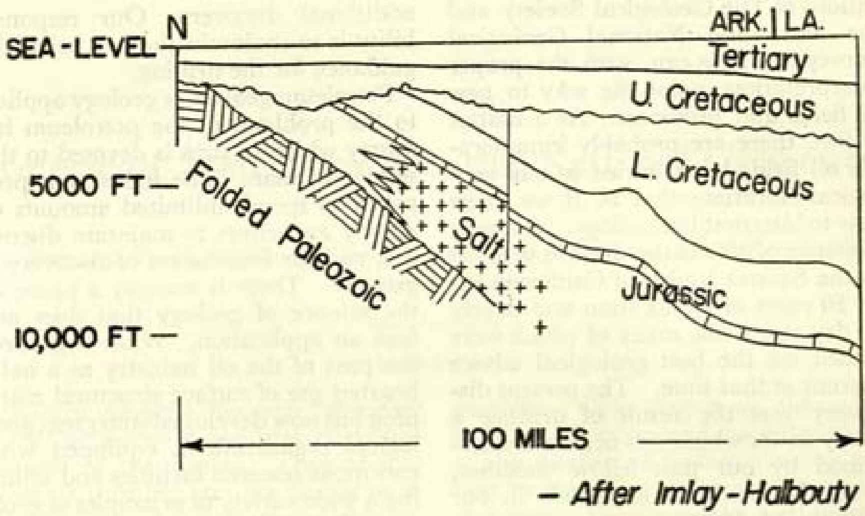

FIGURE 11.—Wedge-shaped Lower Cretaceous and Jurassic sediments of southern Arkansas and northern Louisiana which provide the regional location for more than 125 oil and gas pools.

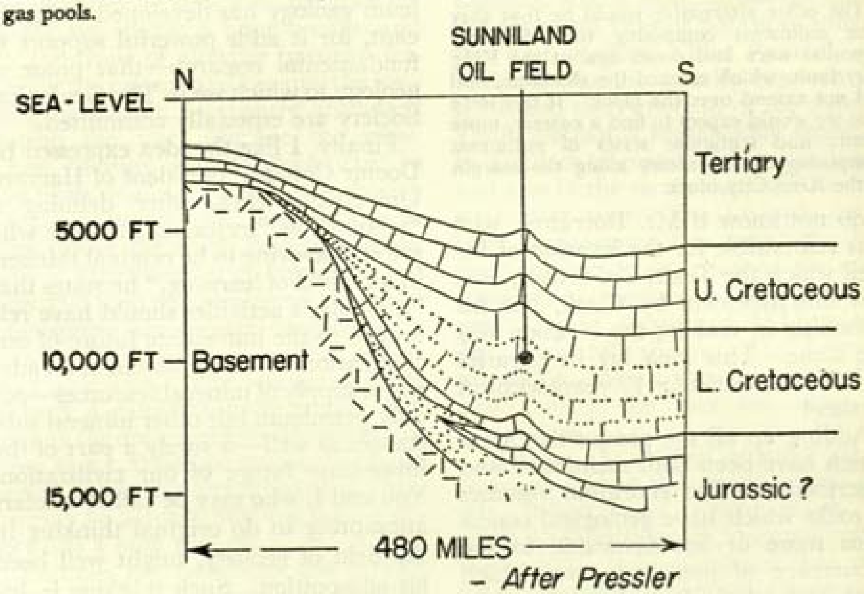

FIGURE 12.—Same wedge-shaped cross section of lower Cretaceous and Jurassic sediments (see fig. 11) extends into Florida where it has been found productive at Sunniland.

changes in facies will occur in these rocks, but their past history in Louisiana and Arkansas gives some indication of the possibilities. The scale, both lateral and vertical, is so great that here, again, if production is found, we can expect it to be substantial in terms of national needs.

Ideas on where to drill come from many sources. The farther away from present production we search, the more we depend on sources outside the petroleum industry for our basic data. One such source is the great wealth of geologic data in the publications of our science and particularly in the publi-

cations of The Geological Society and the State and National Geological Surveys. These can, with the proper interpretation, point the way to new oil fields and provinces. As a matter of fact, there are probably innumerable oil fields lying buried in our geological libraries—that is, if we knew how to interpret the geology. A recent example of this is the discovery of oil in the Salinas Valley of California after 50 years of exploration and nearly 90 dry test wells, many of which were drilled on the best geological advice current at that time. The present discovery was the result of drilling a sandy facies which was accurately described by our past fellow member, Bruce L. Clark, in an article in our Bulletin of 1930. It was covered in two significant sentences:

> The other alternative would be that they (the sediments composing the Monterey deposits) were laid down against the King City fault, which marked the shoreline, and did not extend over the block. If this were true we would expect to find a coarser, more clastic and lenticular series of sediments composing the Monterey along the margin of the King City block.

I do not know if Mr. Dorrance, who was responsible for the location of the well which the Texas Co. drilled, ever saw this statement by Clark, but his reasoning in making the location was the same. This idea lay in libraries all over the world for 17 years without a taker!

Adding up all the prospective areas which have been both mentioned and described, we find enormous volumes of rocks which have geological conditions more or less favorable to the occurrence of petroleum, yet which have had relatively little exploration. The reasonable conclusion is that they contain proportionately large petroleum deposits, and that our exploration job is still far from complete. It is extremely doubtful if the geology of any of these areas will ultimately prove to be exactly as it is now envisioned. As long, however, as favorable geologic factors remain, there is reason for drilling and, if drilling, then hope for additional discovery. Our responsibility is to maintain the best scientific guidance for the drilling.

Petroleum geology is geology applied to the problems of the petroleum industry which in turn is devoted to the service of man. The industry is prepared to spend unlimited amounts of money and effort to maintain discovery, and the foundation of discovery is geology. There is scarcely a phase of the science of geology that does not find an application. What began on the part of the oil industry as a halfhearted use of surface structural mapping has now developed into great geological organizations, equipped with enormous research facilities and utilizing a wide variety of principles of geology, physics, chemistry, and engineering. The broad front on which petroleum geology has developed is significant, for it adds powerful support to fundamental research—that phase of geology to which we in The Geological Society are especially committed.

Finally, I like the idea expressed by Doctor Conant,[2] president of Harvard University, when, after defining a "scholar" as "including all those who are endeavoring to be original thinkers in any field of learning," he states that "a scholar's activities should have relevance to the immediate future of our civilization." The problem of an adequate supply of mineral resources—not only petroleum but other mineral substances as well—is surely a part of the immediate future of our civilization. You and I, who may be called scholars attempting to do original thinking in the field of geology, might well heed his admonition. Such thinking is, indeed, high-level geology. It is a field in which the scholars of The Geological Society of America have played a vital part in the past and are needed more than ever in the future.

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[2] Conant, James B., The American community of scholars. Address delivered at the inauguration of Arthur Holly Compton as Chancellor of Washington University, St. Louis, Mo., February 22, 1946.

American Meteorites and the National Collection

By Edward P. Henderson, *Associate Curator of Mineralogy and Petrology, U. S. National Museum*

[With 6 plates]

Nearly everyone has seen "shooting stars" or meteors and has been impressed by the display. They appear without warning and are best seen at night. They do enter the earth's atmosphere during the daytime but are less likely to be seen then because the bright sky makes a poor background for the trails of glowing particles following the meteor and because the low-hanging clouds, frequently abundant during the day, obscure the view. These "falling stars," which vary in size from small dust particles to bodies weighing many tons, are usually so high above the earth that they make only a silent display of fireworks; but now and then one penetrates the lower atmosphere far enough to give out a strange roaring sound audible over a very wide area. The average observer of such a display usually errs in estimating the distance of the falling meteor from him. When no sound effects are heard within a short interval of time, he may be assured that the falling object was a long way off.

Particles are torn from this rapidly moving object and are sent whirling in its wake. By day only a streak of gray smoke resembling a cloud is visible, but at night a luminous trail may be seen. These trails look small and unimportant compared with our low-hanging cumulus clouds, but their apparent size is deceptive. Floating 30 to 40 miles above the earth, they are, in fact, very large, containing vast quantities of finely divided meteoric particles. This dust from "shooting stars" settles unnoticed upon the earth.

The display of falling meteors can best be seen during certain seasons of the year. There are two well-known streams of meteors, Perseids and Leonids, which have furnished splendid shows on various occasions during the past century. The Perseids are visible in August, usually between the tenth and the twentieth of the month. Their display is remarkably constant in number of meteors seen per hour, and also in the recurrence of the event year after year. The Leonids make their appearance less faithfully, but their showers have furnished the most spectacular displays. The phenomenal Leonid shower of 1833 is still frequently referred to. The Leonids are visible toward the end of October and during the first few days in November.

Meteors are defined as small astronomical bodies that flash across the sky. When these masses reach the earth from outer space, they are called meteorites. It is calculated that millions of meteors enter our atmosphere each day, but records made of observed falls over the past 100 years show that a very limited number fall to the earth and are found. Since these meteors enter the earth's atmosphere from all directions as the earth rotates on its axis, every land area has a chance of being struck.

Some meteorites are large and are capable of doing considerable damage

when they fall. Fortunately, no fall has to date injured or killed anybody as far as authenticated records go. Buildings have been struck, and some day one may fall in a thickly populated zone and take its toll, but that day may be in the far distant future. W. J. Fisher [1] made a study showing that out of a total of 528 witnessed falls for the world, 18, or only 3.4 percent, had struck buildings, and 12, or 2.27 percent, had landed on roads. Hence it will be seen that the risk to an individual is negligible.

The finding of a meteorite depends largely upon natural conditions, such as the abundance of rocks scattered about, and the frequency and completeness with which a district is covered by man. In rugged terrain or in heavily forested areas few finds have been recorded. In areas of our country that have been covered by glaciers, meteorite hunting is very discouraging, as preglacial meteorites are now buried under glacial drift.

Meteorites that fall into the water sink to the bottom and become buried in the sediments forming there. It is not likely that many of these will ever be found, but quite by accident J. O. Neill, who was fishing some three-quarters of a mile from the shore of Lake Okeechobee, Fla., had the rare fortune to recover a small meteorite in his net.

The number of meteorites that reach the earth each year far exceeds the number actually witnessed. The British Museum [2] published a table listing 1,251 different meteorites from the entire world, and of this number 602 were seen to fall and 649 were finds of old falls. The proportion of observed falls to finds in the United States is 97 to 441, or about 1 to 5, whereas in the table referred to it is nearer 1 to 1.

About 10 years ago Smead reported on the frequency of witnessed falls within the various countries of the world, and the figures are given in the last column of the following table.

TABLE 1.—*Area, population, and reported falls of meteorites in five countries**

Country	Area square miles	Population	Population density	Witnessed falls
India	1, 802, 629	352, 837, 778	195	102
United States	3, 026, 789	124, 693, 606	41	79
France	212, 681	41, 834, 923	196	54
Germany	181, 662	64, 600, 000	355	24
Spain	195, 010	22, 760, 854	116	23

* Figures for area and population are from Rand McNally Atlas, 1934. The number of witnessed falls is from J. L. Smead's article in Pop. Astron., vol. 46, p. 331, 1938.

This table, although out of date as to the number of witnessed falls, is of interest in giving the relative proportion of observed falls for these countries. The United States, with its lower population density, has done exceptionally well in recovering freshly fallen meteorites. From the following 17 States no witnessed falls have been reported: Alabama, Arizona, Colorado, Delaware, Florida, Idaho, Louisiana, Massachusetts, Montana, Nevada, New Hampshire, North Dakota, Rhode Island, Utah, Vermont, West Virginia, Wyoming.

Meteorites in the United States

There have been 524 different meteorites found within the limits of the

[1] Pop. Astron., vol. 41, pp. 246–254. 1933.

[2] Second appendix to Catalogue of Meteorites, by Max H. Hey. 1940.

United States up to July 1948, but this figure is only relatively accurate because some of the early discoveries are so closely spaced geographically that in some instances the same meteorite may be listed more than once. New finds are made from time to time, and often considerable time elapses before their existence is reported. Specimens of these meteorites have been identified and preserved in various collections. The vast majority of them are discoveries of old falls; only 97 have been seen to fall. The land area of the United States must have been hit by falling meteorites many more than 535 times, but it is useless to make any estimate of the possible number.

Between 1807 and 1850, 14 falls occurred, and between 1850 and 1900, 28 falls were reported. Since 1900 only 55 falls have been reported. Between 1900 and 1948 there were 14 years in which no meteorites were observed to fall, and in only 4 different years were as many as three or more meteorites seen to fall. In 1933 four different falls were observed in this country, and this is the maximum number ever to be reported in a single year.

Of the 97 witnessed falls in this country, 28 have occurred in the morning, including those reported as occurring at noon, and 61 have fallen in the afternoon. The hour of fall of the others was not recorded, but it is a well-recognized fact that more meteorites reach the earth between noon and midnight than during the morning hours.

There is wide variation in the number of meteorites found in different States. Texas leads the list with 83; Kansas has 54; Colorado, 40; Nebraska, New Mexico, and North Carolina, 29 each; Tennessee, 21; Alabama and Kentucky, 20 each. Only 20 meteorites have been reported from the three States of Ohio (8), Indiana (9), and Illinois (3), doubtless because those States were well covered with glacial drift. In five States—Delaware, Massachusetts, New Hampshire, Rhode Island, and Vermont [3]—no meteorites have been found.

The first of the 97 witnessed American falls occurred on December 14, 1807, when a stone of 150 kg. fell about 6:30 a. m. at Weston, Conn. The next witnessed fall was on Jan. 30, 1810, at 2 p. m., when a 1.3 kg.-stone fell in Caswell County, N. C.[4] At 4:30 p. m. on August 7, 1823, a fall occurred near Nobleboro, Maine, and about noon on February 10, 1825, a stone weighing 7.5 kg. fell at Nanjemoy, Md. These were all stony meteorites. The first known iron meteorite fell in 1835, but the date is not definitely known; it has been reported as July 31 or August 1. This iron, weighing 4.5 kg., struck near Charlotte, Tenn. The largest of the witnessed iron meteorite falls in this country is the Cabin Creek, Ark., meteorite, weighing 48.7 kg., which fell on March 27, 1886.

Table 2 lists the largest individual iron meteorites found in the United States. All these are old and unwitnessed falls. The Sardis iron is the only large meteorite found in the eastern part of the United States.

The largest individual stony meteorite ever found in America is the Norton County, Kans.—Furnas County, Nebr., stone. This was a witnessed fall.

Table 3 lists the largest of our witnessed falls and old falls which have been discovered in the United States.

Kansas and Texas lead the other States in number of large stony meteorites, and it is interesting to note that most of the large stones have been found in the West.

Perhaps the oldest known meteorite, from the standpoint of the time of its fall to our earth, is the 1,760-pound Sardis, Ga., iron (pl. 3, *a*). According-

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[3] One meteorite was reported from Vermont in Science, vol. 96, p. 494, 1942; later proved by author to be manufactured iron.

[4] No specimens of this fall have been preserved; hence some authorities do not list this. However, the evidence seems to justify including it as a witnessed fall.

TABLE 2.—*Largest individual iron meteorites found in the United States*

Name	State	Weight (kg.)	Location of specimen
Willamette	Oregon	14, 175	American Museum of Natural History.
Navajo	Nevada	1, 503	Chicago Natural History Museum.
Quinn Canyon	Nevada	1, 450	Chicago Natural History Museum.
Goose Lake	California	1, 169	United States National Museum.
Sardis	Georgia	800	United States National Museum.
Red River	Texas	743	Yale University.
Tucson	Arizona	688	United States National Museum.
Drum Mountains	Utah	529	United States National Museum.

TABLE 3.—*Largest stony meteorites found in the United States*

Name	Total known weight in kg.	Weight of largest piece	Date of fall	Remarks
	Witnessed			
Norton County, Kans.-Furnas County, Nebr.	1, 038. 5	966. 0	2-18-1948	1,000 fragments.
Paragould, Ark	409. 0	372. 7	2-17-1930	
Estherville, Iowa	337. 0	198. 0	2-10-1879	
New Concord, Ohio	227. 0	46. 8	5- 1-1860	
Holbrook, Ariz	218. 0		7-19-1912	14,000 individuals.
Homestead, Iowa	210. 0	33. 6	2-12-1875	
Weston, Conn	150. 0	91. 0	12-14-1807	
	Unwitnessed			
Long Island, Kans	579. 0	185		4,000 individuals.
Plainview, Tex	520. 0			500 individuals.
Estacado, Tex	412. 0	290		
Hugoton, Kans	340. 0	325		
Morland, Kans.*	283. 0			
Boise City, Okla	181. 9			Many fragments.
Kimble County, Tex	153. 8			
McKinney, Tex	152. 0			

*This meteorite was found in 4 principal pieces, all of which were in contact and evidently were lying in place. The 4 fit together to form an almost complete stone. The second-largest fragment weighed 160 pounds. Trans. Kansas Acad. Sci., vol. 39, pp. 169–183, 1936.

ing to the available evidence, this iron probably fell in the beds from which it was dug in 1940 at the time these sediments were being deposited on the Atlantic Coastal Plain in Miocene times, estimated to be about 30,000,000 years ago. The specimen, when recovered, scarcely resembled a meteorite, its surface being so weathered and sand grains being so mixed with the alteration products that it looked more like an iron-stained sandstone. The excessive weight of the small pieces broken off led the finders to

become interested in learning what made this "rock" too heavy.

The origin of meteorites is a controversial subject and has been purposely omitted from this discussion, but their composition brings to mind the material believed by geologists to occur in the interior of large planets like our earth. In what manner the planet or planets were broken up and how long these individual objects have existed as fragments in outer space before falling upon our earth is a problem for the astronomer. Meteorites, before falling to the earth, existed in an environment very different from that here. They were never exposed to much oxygen or water; hence, in their new terrestrial environment they become subjected to new chemical conditions, and alteration starts rather quickly. The metallic iron in some meteorites soon combines with oxygen and water, and a rust develops on the metal which is similar in appearance to ordinary iron rust.

No simple method has been developed to determine how long a weathered or rusted meteorite may have been on this earth when it is found. Weathering conditions and the nature of the soil in which the meteorite fell differ from place to place, and also some meteorites are less stable or less resistant to weathering than others.

Meteorite Craters

The most spectacular feature connected with any meteorite in the world is the large meteorite crater in Arizona. This is the site where the largest known meteorite crashed into the earth in prehistoric times. The crater is nearly circular in shape, with a diameter of about 1,200 meters and a depth from the rim to the crater floor of 175 meters. This great depression, made by the impact of a falling meteorite, still represents the greatest explosion ever to have taken place on the earth other than some of volcanic origin.

Around the rim of the crater many large masses of meteoric iron have been found. Over 5,000 kg. of meteoric material has been reported, and in addition countless small fragments have been carried away. Canyon Diablo is the name given the meteoric iron from this crater, and it is perhaps the best-known meteorite in the world. The literature on it and on the crater is so extensive that it is not feasible to cite it.

Within the lifetime of many now living, our earth was struck another terrific blow by a falling meteorite. In 1908 a large one fell in Siberia and leveled the forest for miles around. Although no fragments of this have been found to date, there is no question but that this explosion was caused by a meteorite.

There are some other well-known craters in our country from which meteoric material has been obtained. The second largest is the Odessa, Tex., crater, which has a diameter of about 170 meters but a depth of only 5 meters. The third largest is the Brenham, Kans., crater which is about 17 meters in diameter and about 3 meters deep.

The National Collection of Meteorites

The collection of meteorites in the United States National Museum contains representative samples of 379 of the 524 different meteoritic falls which have occurred in this country. This is slightly more than 70 percent of all known American meteorites, and constitutes an adequate representation of the different varieties and peculiarities of meteorites.

Meteorites may fall anywhere on earth, and it is now known through specimens which have been identified and preserved in collections that there have been about 1,450 different falls and finds of meteorites. There are specimens of 388 different falls from outside the limits of our country in the National collection; these are sizable samples that adequately represent the meteorites. The collection thus contains representative samples of 52 percent of the known meteoritic falls in the world and hence is an important

source for research material. This collection is important not only because of its size and completeness, but also because all the meteorites in it have been studied and the information thus obtained has been classified. Over 100 different publications have been issued describing meteoritic material on deposit in the Museum.

The first publication of the National Museum relating to meteorites appeared in 1888, when Dr. George P. Merrill published a description of the stone from Bluff, Tex. The next to be issued, in 1894, was the description of the stone from Beaver Creek, British Columbia. The growth and importance of the collection are largely due to the lifetime work of Dr. Merrill. He described 65 different falls and also published several general papers on the structure and composition of meteorites.

The Museum also maintains a catalog of all known metoritic material of the world. The foreign meteorites are listed under the countries in which they have been found; those from the United States are listed under their respective States and also by the latitude and longitude of the place of their discovery, so that when new material comes in, it can be proved to be either a new fall or part of an old, well-known one.

An extensive metallographic study has been made of the iron meteorites, and 1,933 microphotographs, each with its metallographic description, have been made of 144 different meteorites. This represents the work of Stuart H. Perry, associate in mineralogy, who has carried on this study for many years.

How To Recognize a Meteorite

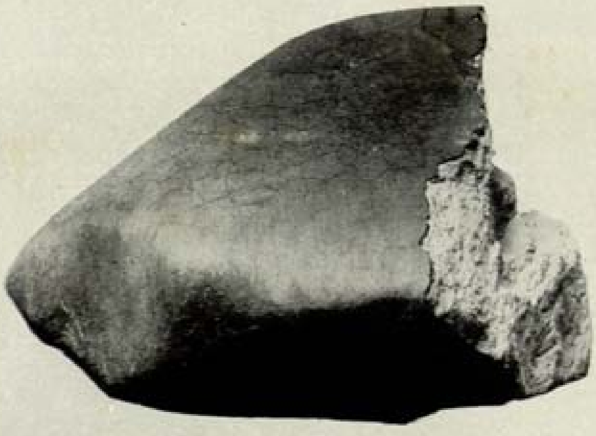
The physical features of a meteorite are sufficiently constant so that after one has seen several or carefully exame ined good illustrations of them, the identification of a possible meteoritie specimen should be reasonably simpls and accurate. The specific test needed to determine the meteoritic nature of either a stone or an iron should be performed by someone who is familiar with them, as now and then unusual specimens are found, the analysis of which requires a trained worker.

The external portions of both stony and iron meteorites show evidence of their struggle to penetrate our atmosphere. The outer portion of a fallen meteorite is covered with a thin crust of fused material (pl. 1, *b*). Sometimes stones and irons are fragmented before the end of their flight and then their surfaces are not entirely covered with fused material. Stony meteorites are sometimes so friable, or loosely bonded together, that they may break apart on striking the earth. Iron meteorites have been found with small areas of their surface broken off toward the end of the flight. It has already been noted that our largest meteorites are metallic, apparently for the reason that they are less likely to break apart on falling than the stony varieties.

During the few seconds in which a falling meteorite has a high velocity, the frictional heat generated by the air resistance causes the outermost crust to fuse. This film of fused material can never become very thick (pl. 1, *b*), because the air friction erodes the material away as it forms. Thus the crust found on a meteorite is the material that fused probably not very far above the surface of the earth.

It is a surprise to many people to learn that meteorites are not masses of fused molten material. The centers of these objects show no indication of having been very hot during their fall. In fact most of the heat noticed on collecting a freshly fallen meteorite is believed to be heat that results from the impact of the object with the ground. Some of the freshly fallen American meteorites have been noticeably cold to the touch when recovered immediately after their fall. The 62½-pound stone which fell near Allegan, Mich., was recovered within a few moments after its fall, and the sand

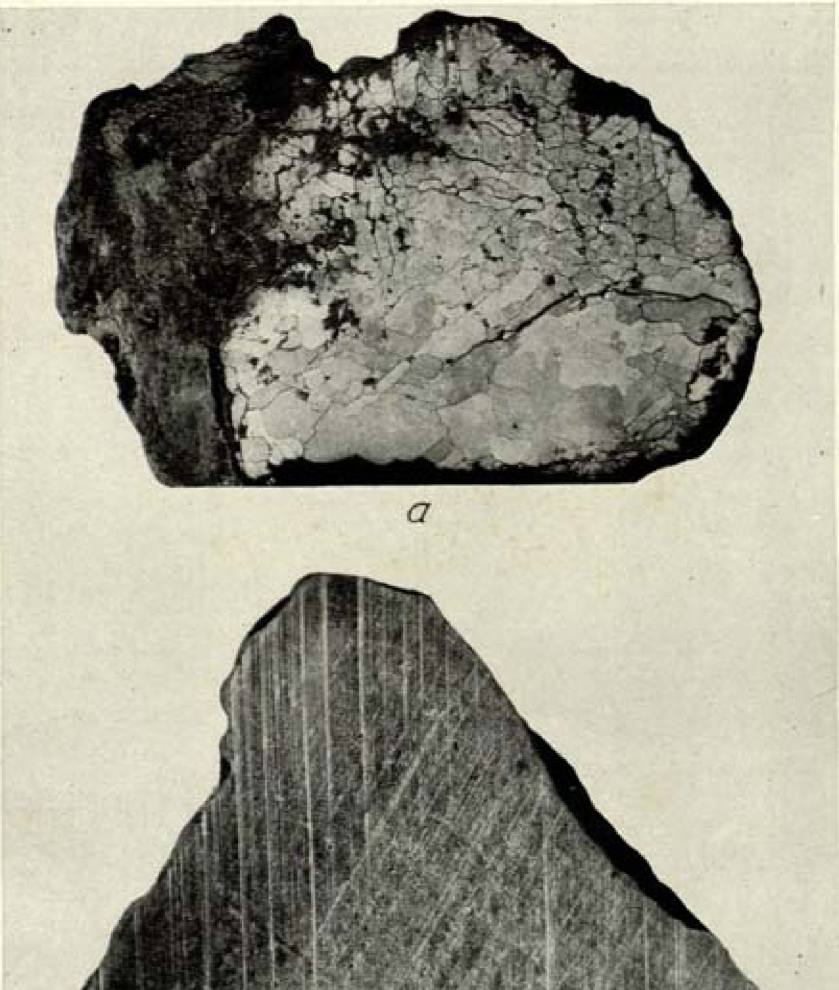
a



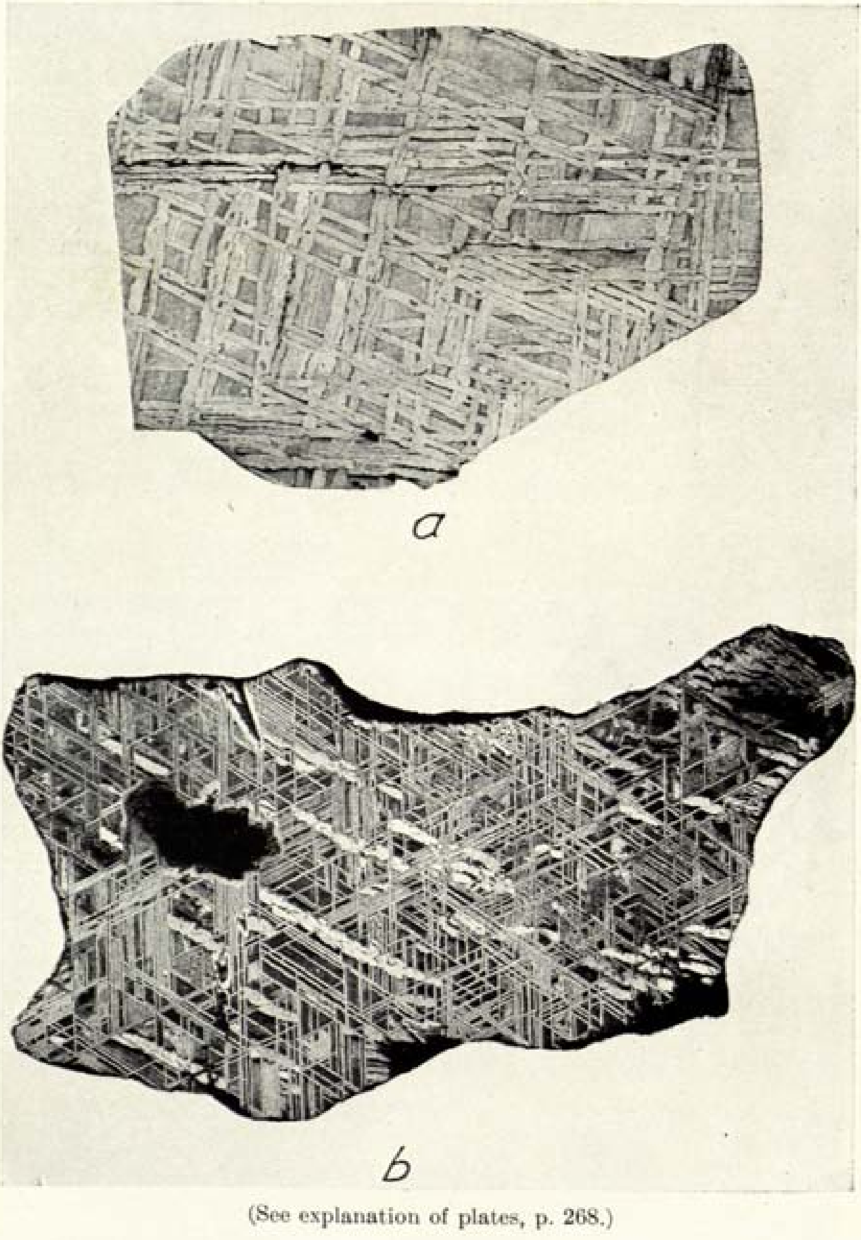
b

(See explanation of plates, p. 268.)

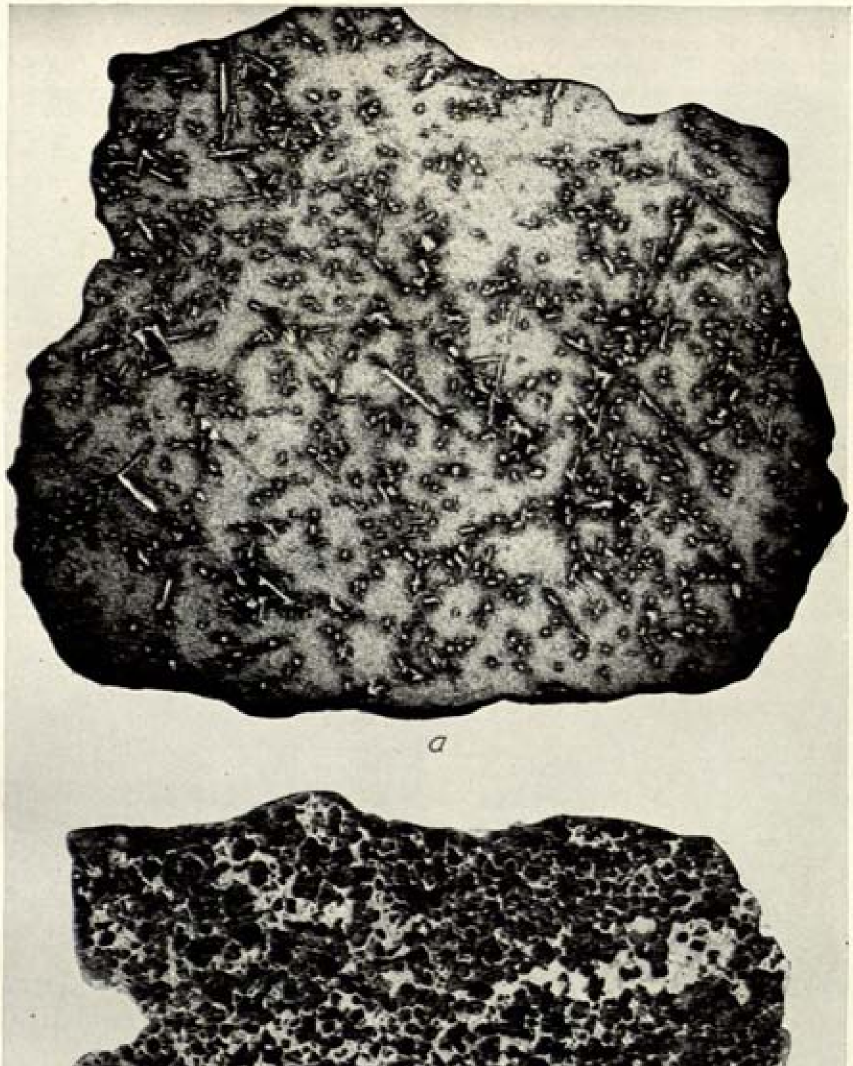
(See explanation of plates, p. 268)



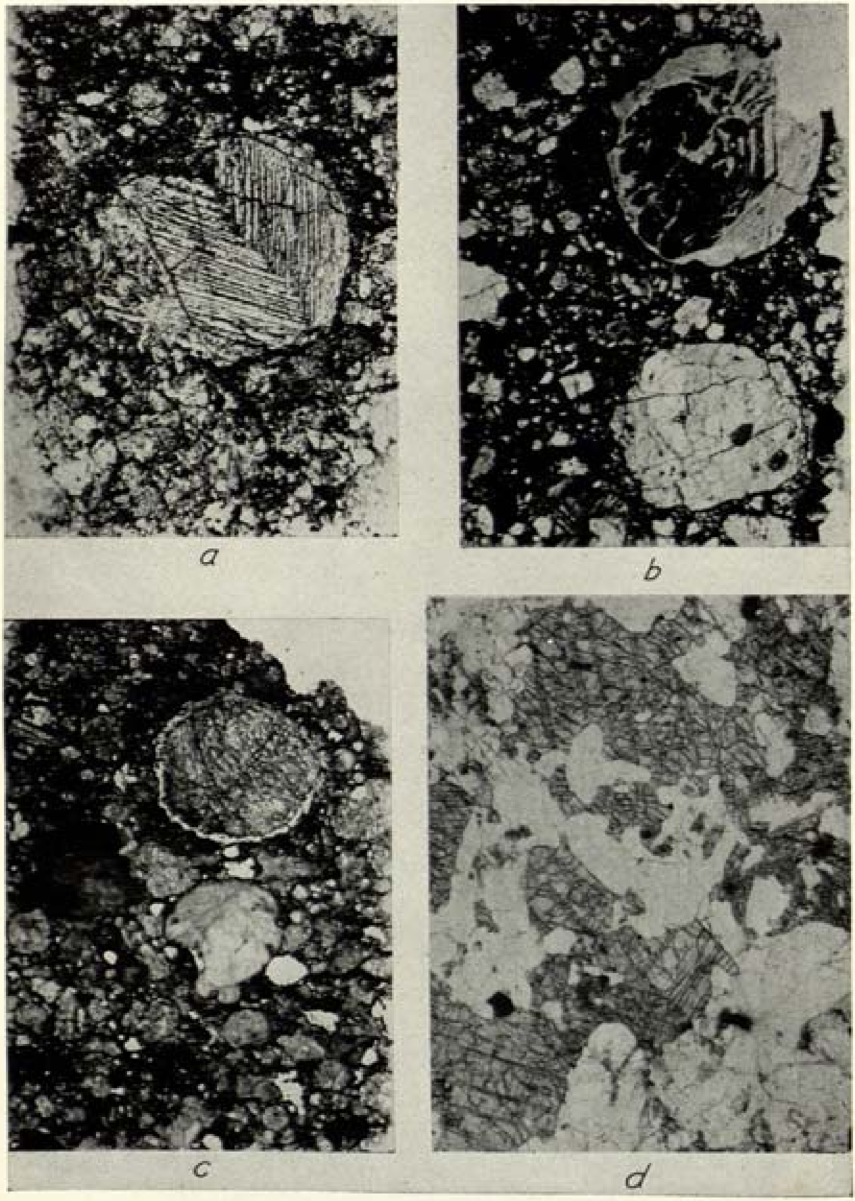
(See explanation of plates, p. 268.)



(See explanation of plates, p. 268.)



(See explanation of plates, p. 268.)



(See explanation of plates, p. 268.)

was hot for about 2 feet from the place of impact. This stone fell upon dry grass, and grass was welded into the fractures of the mass by the impact but was not charred. Hence the meteorite itself was not very hot when it fell. The Colby, Wis., stone was recovered a few minutes after falling and when dug up and exposed to the air was so cold that frost immediately formed on the surface. Another such example of a cold meteorite is the Tilden, Ill., fall, parts of which were recovered at several different places along a path of about 3 miles, and each specimen was reported by different finders as being cold when first touched. These various meteoritic falls all had fusion crusts over the outer surface, but the main mass was cold inside as there was not time enough during the flight for the interior of the mass to become even warm.

The crust on freshly fallen meteorites may have delicate lines formed by the air dragging the softened material away from its foreward face (pl. 1, *a*). These lines, or flight markings, reveal the orientation of the mass during the last moments of its flight. Usually the crust is thin on the front face and shows some accumulation on the side and rear faces. No part of the crust is ever very thick, and since there are usually some silicate minerals containing iron, the crust on freshly fallen stones is generally black. Some of the rarer types of stony meteorites are made up of minerals so free of iron that the fused crust is cream-colored to gray. Freshly fallen iron meteorites are covered with a black crust which has a submetallic luster.

If the specimen is an old fall the crust probably has been altered to a brownish color on both the stony and iron meteorites. Prolonged weathering may further modify the crust until most of the flight markings are obliterated. In the case of stony meteorites prolonged weathering penetrates the mass and the entire stone becomes rather evenly discolored with brown hydrous iron oxide. Iron meteorites, being less porous, weather more gradually than stones. Although weathering may be so extensive that the surface retains none of the original flight features, the interior of the iron may be bright, fresh metal (pl. 3, *a*). Iron meteorites have been found in which the entire mass has been altered to a brown oxide, but these are unusual examples.

Another rather characteristic feature of a meteorite is the presence of shallow depressions on the surface, called "thumb marks" because of the resemblance to the imprint of the thumb on a plastic medium (pl. 2). These originate during the flight of a meteor through the atmosphere and are caused by the scouring action of the air; since they are rather deep, they are not readily lost by weathering. These "thumb marks" are very different in appearance from the rounded holes found in slags and furnace products so frequently mistaken for meteorites. In fact, meteorites will not, on first inspection, appear to have been affected by heating.

Meteorites are heavy, weighing more than the average terrestrial rock of equivalent size. Hence any unusually heavy specimen showing "thumb marks" and what appears to be a fusion crust over the surface should be investigated. The finder of such a specimen should spend several minutes looking around to become familiar with the variety of terrestrial rocks existing in that area. If by chance a meteorite has been discovered, it will become evident at once that the specimen is noticeably different from the rocks in the vicinity. If there are numerous boulder or rock fragments scattered about, a genuine meteorite will differ in weight, shape, and crust from the average rock. If the area contains very few rocks, then any single unusually heavy specimen whose occurrence cannot be readily explained as being natural to the place should be looked upon as a possible meteorite.

Many meteorites are made entirely of metal and hence are much heavier

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than the stony varieties. An iron meteorite is readily attracted to a magnet, but of course so is ordinary cast iron, as well as some varieties of iron ore. If the specimen has the characteristic external features of a meteorite referred to above, it should be investigated.

Hit the sample with a hammer to see if small pieces can be broken off. If the fragments removed have a brownish or black color, test it further by pounding it upon a rock or anvil. Iron ores are brittle, and hence easily reduced to a powder, which may be brown, red, or black depending upon which of the iron minerals has been found. Both meteoric iron and manufactured iron are very tough, and pounding with a hammer does not affect them much. Samples not affected by pounding should be tested with a file or whetstone, either of which will develop a silvery-colored spot if the sample is a metal.

The finding of any metallic object suspected of being a meteorite should be checked by someone familiar with the identification of meteorites. Cut a small protruding portion from the mass with a hacksaw and send it to some institution engaged in the study of meteorites, together with information concerning the locality where the specimen was found.

If the person finding the iron is experienced and equipped to make certain specific tests, the metal can be ground down until a polished surface is obtained and this etched with dilute nitric acid. Repeated etchings are made until the structural pattern is developed on the polished surface. If the specimen being tested is a meteorite, it will probably have structures similar to those shown in the illustrations in this paper (pls. 3, 4, 5). Another chemical test which it is worth while to make is that for nickel, as all metallic meteorites contain nickel. Persons making the etch test should have their results checked, as the etch structures of meteorites are variable, and some of the rarer types of meteoritic irons could easily be overlooked if only etch tests are made.

There are several kinds of iron meteorites, the various types being identified by the different etch patterns displayed. The simplest type is the hexahedrite, which consists of only one phase of iron and nickel and is usually characterized by a well-developed series of Neumann lines (pl. 3, *b*). This group contains about 5.5 percent nickel, and when the percentage of nickel is no greater, the iron is capable of retaining the nickel in solution; hence, hexahedrites consist of a single alloy of iron and nickel.

Meteorites with higher percentages of nickel have two alloys present, one of which has the same composition as the hexahedrite and is called kamacite, and the second, richer in nickel, is known as taenite. These alloys separate out into platy structures resembling the habit shown in plate 4. This structure is known as a Widmanstatten pattern, and a meteorite with this habit is classified as an octahedrite (pl. 4). Meteorites having higher percentages of nickel usually have narrower bands of kamacite; hence octahedrites may be subdivided into coarse, medium, and fine, depending upon the width of the kamacite bands.

Some metallic meteorites, when etched, lack a well-developed structure; these are called ataxites (pl. 5, *a*). They have an etch pattern which those inexperienced in meteorites might fail to recognize.

There are meteorites which contain almost equal quantities of stony and metallic constituents. One such example is a pallasite (pl. 5, *b*) consisting of a silicate mineral, olivine, which is enclosed in a network of metal.

Stony meteorites are heavy because the principal component minerals, pyroxene and olivine, have specific gravities slightly over 3, and also because most of them contain an appreciable percentage of metallic inclusions. Beneath the outer crust of a stony meteorite is usually found a fine-grained aggregate of minerals. These may or may not be firmly bound

together. Many stony meteorites are relatively friable.

By far the greatest number of stony meteorites contain rounded silicate bodies called chondrules (pl. 6, *a*, *b*, *c*). These, as a rule, are small and are not glassy like the quartz grains in a sandstone but are composed of bladed or needlelike crystalline aggregates usually of a single type of mineral, although sometimes two minerals will be enclosed in the rounded body. Nothing closely resembling chondrules has been found in our terrestrial rocks. The finder of a suspected stony meteorite should, if possible, grind down a small area by holding the mass against a grindstone. Structures such as those shown in plate 6, *b*, can then be more easily seen, especially if the surface is dampened with water and examined with a magnifying glass.

Some of the rarer types of stony meteorites do not have these chondrules, and an even more limited number lack metallic inclusions. Hence the finder of a specimen believed to be a meteorite and having some of the features mentioned above should submit the specimen to someone experienced in the identification of these objects.

The most abundant mineral in the rocks of our earth is quartz, a substance that very rarely occurs in meteorites. The few minerals that are common to both terrestrial rocks and stony meteorites have identical compositions in each, but the habit or physical structure of the meteoritic minerals is very distinct from that of the same minerals occurring in ordinary rocks. As yet, no definite reason is known for this difference in structure, but the fact that there is such a difference is fortunate in that it permits the definite identification of meteoritic stones.

Meteorites have been found to contain minute traces of precious metals, as well as diamonds (not gem quality), but never in commercial quantities. Meteorites have no intrinsic value, but are important because scientific information can be obtained from their study.

TABLE 4.—*Witnessed falls of stony meteorites in the United States*

	Year	Month	Day	A. M.	P. M.	Weight in kg.
ALABAMA:						
Athens	1933	7	11	9:30	....	0.265
Danville	1868	11	27	....	5:00	2.04
Felix	1900	5	15	11:30	....	3.2
Frankfort	1868	12	3	....	3:00	.722
Leighton	1907	1	12	....	8:00	.877
ARIZONA: Holbrook	1912	7	19	....	7:15	218.0
ARKANSAS:						
Fayetteville	1934	12	26	11:58	....	2.37
Miller	1930	7	13	9:00	....	16.7
Paragould	1930	2	17	4:08	....	409.0
COLORADO: Johnstown	1924	7	6	....	4:20	40.3
CONNECTICUT: Weston	1807	12	14	6:30	....	150.0
GEORGIA:						
Forsyth	1929	5	8	....	3:30	16.0
Lumpkin	1869	10	6	11:45	....	.357
ILLINOIS:						
Benld	1938	9	29	9:00	....	1.77
Tilden	1927	7	13	....	1:00	74.8
INDIANA:						
Harrison	1859	5	28	....	4:00	.70
Rochester	1876	12	21	....	8:45	.34

TABLE 4.—*Witnessed falls of stony meteorites in the United States*—Continued

	Year	Month	Day	A. M.	P. M.	Weight in kg.
IOWA:						
Estherville	1879	5	10	....	5:00	337.0
Forest City	1890	5	2	....	5:15	122.0
Homestead	1875	2	12	....	10:15	227.0
Marion	1847	2	25	....	2:45	28.3
KANSAS:						
Beardsley	1929	10	15	....	11:30	12.55
Farmington	1890	6	25	....	1:00	89.2
Modoc	1905	9	2	....	9:30	32.8
Norton County [1]	1948	2	18	....	4:45	1,038.5
Ottawa	1896	4	9	....	6:15	.84
Saline	1898	11	15	....	9:30	31.0
KENTUCKY:						
Bath Furnace	1902	11	15	....	6:45	86.6
Cumberland Falls	1919	4	9	12:00	....	24.12
Cynthiana	1877	1	23	....	4:00	6.0
MAINE:						
Andover	1898	8	5	7:30	....	3.40
Castine	1848	5	20	4:00	....	.093
Nobleboro	1823	8	7	....	4:30	2 or 3
Searsmont	1871	5	21	8:15	....	5.4
MARYLAND:						
Nanjemoy	1825	2	10	12:00	....	7.5
St. Mary's County	1919	6	20	....	6:00	.024
MICHIGAN:						
Allegan	1899	7	10	8:0	....	30.45
Rose City	1921	10	17	....	11:00	11.01
MINNESOTA: Fisher	1894	4	9	....	4:00	5.6
MISSISSIPPI:						
Baldwyn	1922	2	2	(Day time)	....	.345
Pelahatchee	1910	10	17	....	....	....
MISSOURI:						
Archie	1932	8	10	....	4:30	5.05
Baxter	1916	1	18	9:00	....	.611
Cape Girardeau	1846	8	14	....	3:00	2.35
Little Piney	1839	2	13	....	3:30	22.7
Warrenton	1877	1	3	7:15	....	45.0
NEBRASKA: Sioux	1933	8	8	10:30	....	4.1
NEW JERSEY: Deal	1829	8	15	12:30	....	.014
NEW MEXICO:						
Aztec	1938	2	1	....	5:00	2.83
Pasamonte	1933	3	24	5:04	....	4.0
NEW YORK: Bethlehem	1859	8	11	7:30	....	.011
NORTH CAROLINA:						
Bald Mountain	1929	7	9	....	p.m.	3.7
Castalia	1874	5	14	....	2:30	7.3
Caswell County	1810	1	30	....	2:00	1.36
Cross Roads	1892	5	24	5:00	....	.167
Farmville	1934	12	4	....	1:00	56.1
Ferguson	1889	7	18	....	6:00	.226
Flows	1849	10	31	....	3:00	8.8
Moore County	1913	4	21	....	5:00	1.86
Rich Mountain	1903	6	30	....	2:00	.668
NORTH DAKOTA: Richardton	1918	6	30	....	10:00	91.0

[1] Norton County, Kans.—Furnas County, Nebr.

TABLE 4.—*Witnessed falls of stony meteorites in the United States*—Continued

	Year	Month	Day	A. M.	P. M.	Weight in kg.
OHIO:						
New Concord	1860	5	1	....	12:45	227.0
Pricetown	1893	2	13	....	....	.9
OKLAHOMA:						
Atoka	1945	9	17	....	6 or 7	2.85
Blackwell	1906	5	?	....	9:00	2.38
Crescent	1936	8	17	....	7:00	.08
Leedey	1943	11	25	....	7:00	50.0
Walters	1946	7	28	....	3:45	28.3
PENNSYLVANIA:						
Chicora	1938	6	24	....	6:05	.303
Black Moshannon	1941	7	10	6:30	....	.523
Bradford Woods	1886	....	....	....	....	.762
SOUTH CAROLINA:						
Bishopville	1843	3	25	....	....	6.0
Cherokee Springs	1933	7	1	9:42	....	8.4
SOUTH DAKOTA: Bath	1892	8	29	....	4:00	21.2
TENNESSEE:						
Drake Creek	1827	5	9	....	4:00	5.4
Petersburg	1855	8	5	....	3:30	1.7
TEXAS:						
Blanket	1909	5	30	....	10:30	5.1
Florence	1922	1	21	....	8:00	3.64
Kendleton	1939	5	2	....	7:25	6.93
Kirbyville	1906	11	12	....	3:30	.097
Pena Blanca Springs	1946	8	2	....	1:20	70.0
Plantersville	1930	9	4	....	4:00	2.08
Troup	1917	4	26	8:30	....	1.13
VIRGINIA:						
Forksville	1924	7	16	....	5:45	6.06
Richmond	1828	6	4	8:30	....	2.0
Sharps	1921	4	1	....	....	1.26
WASHINGTON: Washougal	1939	7	2	7:45	....	.22
WISCONSIN:						
Colby	1917	7	4	....	6:20	104.5
Kilbourn	1911	6	16	....	5:00	.772
Vernon County	1865	3	26	9:00	....	1.5
WYOMING: Torrington	1944	9	23	....	12:30	.259

TABLE 5.—*Witnessed falls of iron meteorites in the United States*

	Year	Month	Day	A. M.	P. M.	Weight kg.
ARKANSAS:						
Norfolk	1918	10	....	....	....	1.05
Cabin Creek	1886	3	27	....	3:00	48.7
CONNECTICUT: Newton	1925	12	29	....	5:00	.212
GEORGIA: Pitts	1921	4	20	9:00	....	3.72
MICHIGAN: Seneca Township	1903	6	....	....	p. m.	11.5
TENNESSEE: Charlotte	1835	7 8	31 1	....	2 or 3	4.5

EXPLANATION OF PLATES

Plate 1

a, Pima County, Ariz. During the fall of this iron through the air the surface was heated by air friction until the metal flowed. Such structures are known as flight markings.

b, Allegan, Mich. The crust on this freshly fallen stony meteorite is black, checked, and smooth because the stone is friable, hence easily eroded away by the air during flight.

Plate 2

A portion of the meteorite exhibit in the U. S. National Museum. The three large iron meteorites in the foreground are, from left to right: Drum Mountains, Utah; Canyon Diablo, Ariz.; Owens Valley, Calif. These show characteristic surfaces of iron meteorites. The pittings are frequently referred to as thumb marks.

Plate 3

a, Sardis, Ga. The dark area at the left shows the weathered surface with no characteristic meteoric features. The dark border surrounding the metal and the network of veins extending into the unaltered metal show how alteration attacks an iron. The surface of this fragment resembles a sandstone, because sand grains from the beds from which it was recovered have been bonded together by the iron oxide (rust) from the buried meteorite.

b, Bennett County, S. Dak. A remarkably large single crystal of kamacite. The delicate series of parallel bands are known as Neumann lines. This type of meteorite is a hexahedrite. The dark inclusions are troilite (iron sulfide). This iron contains 5.25 percent Ni.

Plate 4

a, Aggie Creek, Alaska. A medium octahedrite. The narrow lathlike bands are kamacite and each is bordered by delicate lines of another alloy of iron and nickel, taenite (not discernible in this picture). This iron contains 8.54 percent Ni.

b, Edmonton, Ky. A fine octahedrite. The kamacite bands are narrow. The dark angular areas enclosed within the kamacite bands are plessite, which is an unresolved mixture of kamacite and taenite. The large dark inclusion, left, is troilite. There are several large, irregular, elongated kamacite areas, light-colored in the picture, which are unconformable to the fine octahedral pattern of this meteorite. This iron contains 12.57 percent Ni.

Plate 5

a, Wiley, Colo. Iron meteorites lacking a well-developed etch pattern are classified as ataxites. The small spindles are kamacite. This iron contains 11.71 percent Ni.

b, Mt. Vernon, Ky. The dark mineral is olivine and the light-colored areas are metal. This type of a meteorite is known as a pallasite.

Plate 6

a, Roy, N. Mex. Stony meteorites containing these rounded bodies are classified as chondrites. The large chondrule consists of bands of olivine separated with a black glass.

b, Elm Creek, Kans. Several different kinds of chondrules may occur in the same meteorite. One of these chondrules contains a euhedral crystal of olivine surrounded by the same mineral but with a different structure. The other chondrule consists of separate fragments of olivine. The ground mass is composed of broken fragments of minerals in a black glass.

c, Tennaselm, Esthonia. A chondrule surrounded by a rim of metal. Many colorless areas in the ground mass are metallic inclusions. Metal rarely occurs within a chondrule.

d, Moore County, N. C. A thin section of a meteorite containing no chondrules. Meteorites of this type are called acondrites. They have structures more comparable to terrestrial rocks than any other group of meteorite. The dark areas are pyroxene minerals and the light areas are feldspars.

Glacial Varved Clay Concretions of New England

By Ray S. Bassler, *Head Curator, Department of Geology, U. S. National Museum*

[With 12 plates]

A strange but wholly natural phenomenon startled the people of the southern tip of Maine one morning in 1670. A hillside about 130 feet back from the Kennebunk River bank let loose, jumped over the intervening woods turning upside down on the way, and landed in the river channel, thereby damming it for a spell. The occurrence was recorded by William Hubbard in his "History of New England" (1815), as follows:

> At a place called Kennebunk at the northeast side of Wells in the Province of Maine, not far from the river side, a piece of clay ground was thrown up by a mineral vapour over the top of high oaks that grew between it and the river. The said ground so thrown up fell in the channel of the river, stopping the course thereof, and leaving an hole forty yards square in the place whence it was thrown, in which were found thousands of round pellets of clay, like musket bullets. All the whole town of Wells are witnesses of the truth of this relation; and many others have seen sundry of these clay pellets which the inhabitants have shewn to their neighbours of other towns.

Later in the same year, John Winthrop, Governor of Connecticut, in the Winthrop Papers of the Massachusetts Historical Collection, described "the strãge and prodigious wonder" in more detail:

> The relation w^{ch} I have frõ credible persons concerning the manner of it is this: That the hill being about 8 rods frõ Kennebunke rivers side, on the west side of the river about 4 miles frõ the sea, was removed over the drye land about 8 rods, and over the trees also w^{ch} grew betweene the hill & y^{t} river, leaping over them into y^{t} river, where it was seene placed, wth the upper part downward, & dammed up y^{t} river for a tyme till the water did worke it selfe a passage thorow it. The length of the hill was about 250 foote, the breadth of it about 80 foote, the depth of it about 20 foote. The situation of the hill as to the length of it was norwest & southeast. The earth of it is a blew clay wthout stones, many round bullets of clay were wthin it w^{ch} seem to be of the same clay hardned * * * I had from them (Major William Philips and Mr. Herlakendine Symonds) some few of those round bullets, & small pieces of the earth in other forms, w^{ch} were found vpon that now vpper part w^{ch} was before the lower, or inward bowells of y^{e} hill, as also a small shell or 2 of a kind of shellfish vsuell in many places of the sea, but how they should be wthin y^{t} hill is strãge to cõsider. I have sent all y^{t} I had of thẽ amongst other things to y^{e} Royall Society for their repository.

Governor Winthrop's specimens, upon receipt by the Royal Society, were cataloged in their Journal Book for 1734 as "clay generated in the form of horseshoes, from the bottom of the Connecticut River." The error of locality did not matter since these claystones, as they were then named, occurred in equal abundance along both the Connecticut and Kennebunk Rivers.

More than two centuries after the Kennebunk slide, Edward E. Bourne in his "History of Wells and Kennebunk" (1875) wrote:

> Concerning the overturned hill, it is wished that a more certain and punctual relation might be procured of all the circumstances of the accident. * * * No intelligent person of the present day can hesitate a moment as to the explanation of this strange event. The same thing has occurred several times within the last fifty years. Oak trees then stood all along the banks of the rivers, and this wonder was one of those avalanches

from the banks which have been of so frequent occurrence. * * * The little pellets, which were spoken of as seen after the slide, were rolled up by the avalanche as it passed over the solid ground beneath.

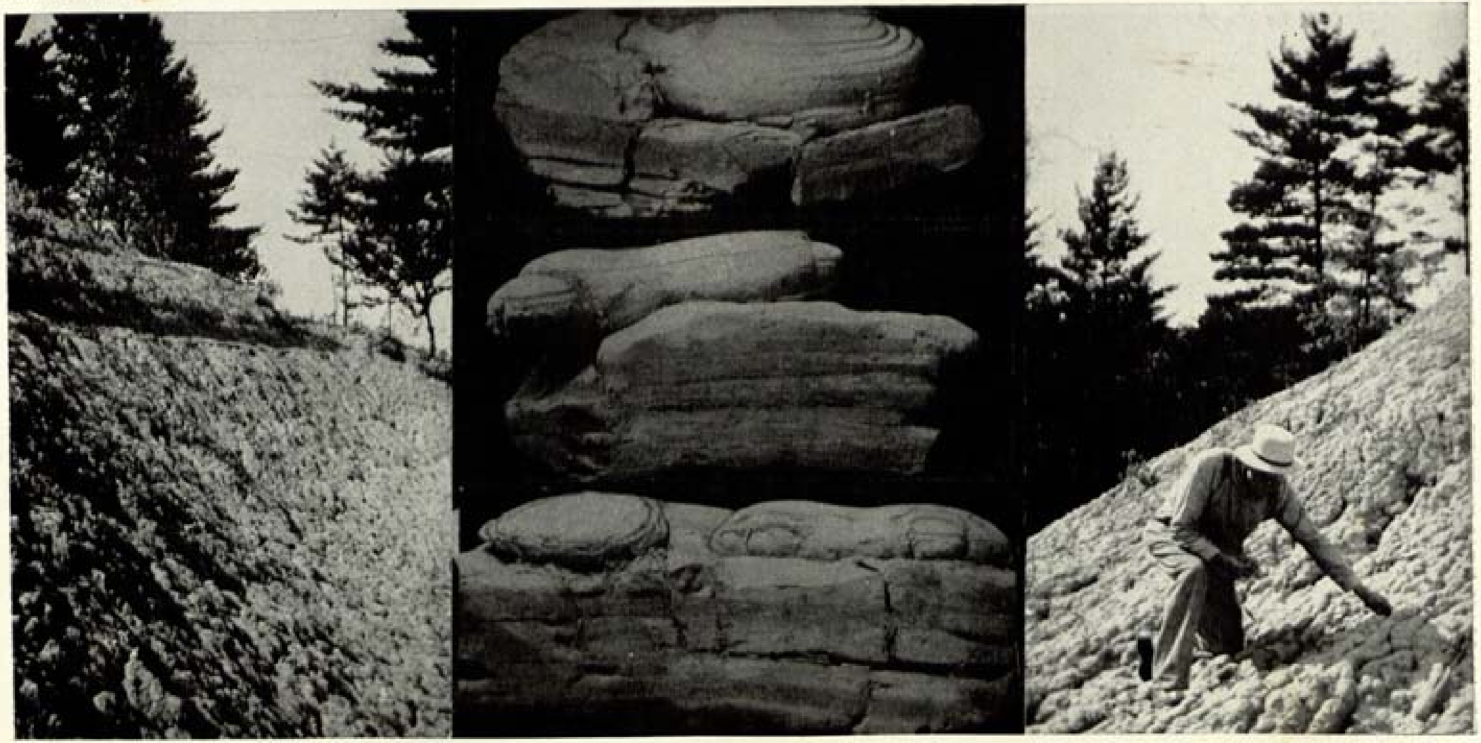
Mr. Bourne undoubtedly recognized the phenomenon as one of the landslides of common occurrence with accompanying clouds of dust in any area where outcropping strata, especially moistened clay beds, slip to lower levels by weathering and gravity. His explanation of the origin of the little pellets, claystones or concretions as now generally designated, was not such a happy one.

From time to time there were other references, particularly to the Connecticut Valley concretions, wherein quite different views were expressed as to their origin. Many people honestly believed they were fossil animals of prehistoric time and called them clay dogs. The regularity of the discoidal forms seemed to prove that they had been turned out on a lathe and had been used for money. A few persons surmised that running water had worn them into their present shapes. Still others thought they were sports of nature or were of supernatural origin. The doll-like forms found in clay banks of the South were explained thus by the old colored mammies: "When the good Lord formed these little children out of clay He forgot to breathe the spirit of life into some of them."

In time, chemical analyses gave a clue to the source of these curiosities. The hard claystones revealed 40 to 50 percent calcium carbonate in their composition, while the soft clay layers in which they were embedded showed only 2 to 3 percent. It seemed therefore probable that the original clay beds had been robbed of their carbonate content by circulating ground waters which in turn had deposited this lime around centers of attraction, thereby building up the claystones. Accordingly, they must have been formed after the deposition of their containing beds; in other words, they were of secondary origin. Various other types of concretions indicate their formation at the same time as the enclosing beds, wherefore they are classified as primary in origin and must be explained differently.

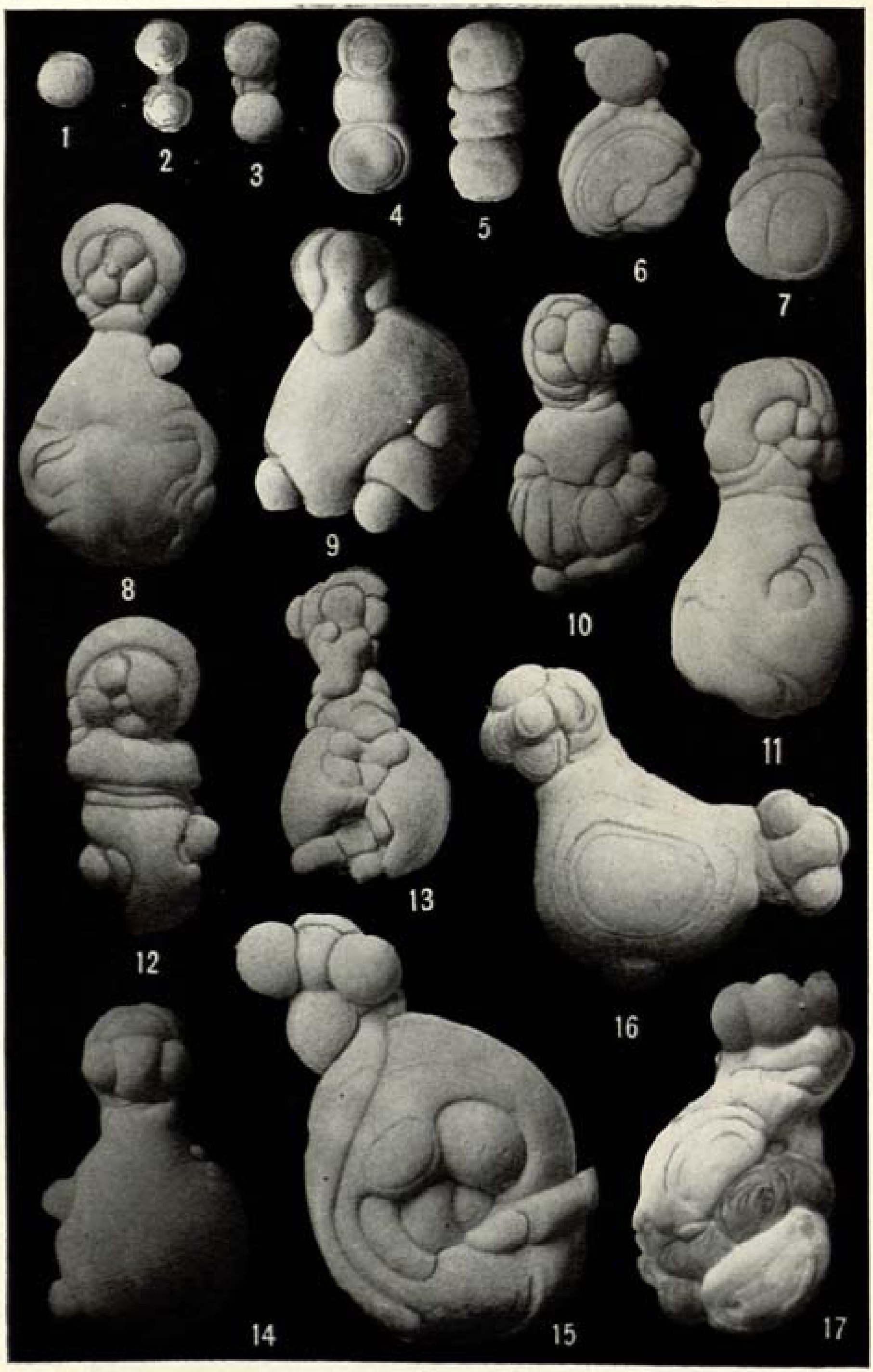
Collecting concretions as a hobby has been a lifelong pleasure of many persons occupied otherwise in quite different pursuits. Among the several publications on New England concretions, was a little-known memoir "Concretions from the Champlain Clays of the Connecticut River Valley," published privately by Mrs. Jennie M. Arms Sheldon in Boston, 1900. Mrs. Sheldon's work was based upon a series of 1,400 specimens, but the present writer had the advantage of studying a collection of more than 3,000 selected examples, the generous gift of the late H. N. Pringle of Washington, D. C., to the United States National Museum. Mr. Pringle, while occupied professionally in Washington, spent many summer vacations near Ryegate, Vt., on the Connecticut River, a locality long noted for its abundant well-preserved concretions. Here, as shown on plate 1, they are found in outcrops of the thin-bedded glacial clays exposed on Clay Island, a mound about 75 feet high nearly encircled by the Connecticut River and Sly Brook. Choice specimens from Mr. Pringle's collection illustrating the origin and progressive growth of these objects now adorn an exhibition case in the Museum's hall of physical geology (pl. 12), while the examples figured on the other accompanying plates are preserved as type specimens with many others in the study series of the department of geology. From the types figured it would appear that all the Ryegate specimens were exceptionally perfect. This, however, is not true, because these types are only examples selected from thousands of bullet and pebble-shaped, spherical, flattened, and all sorts of irregular forms which had not attained complete development.

To understand the formation and



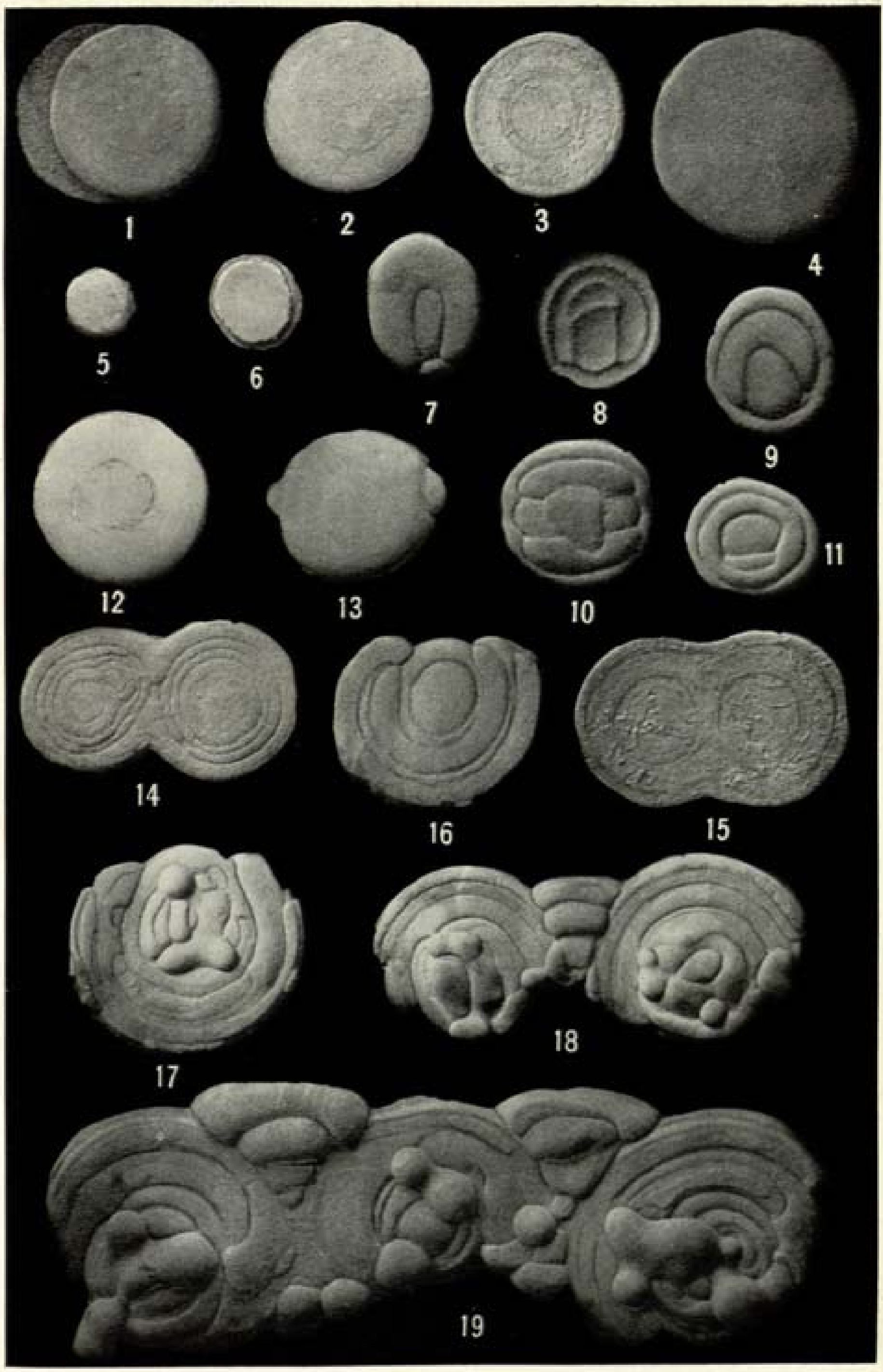
CONCRETION LOCALITY AT RYEGATE, VT.

(See explanation of plates, p. 275.)



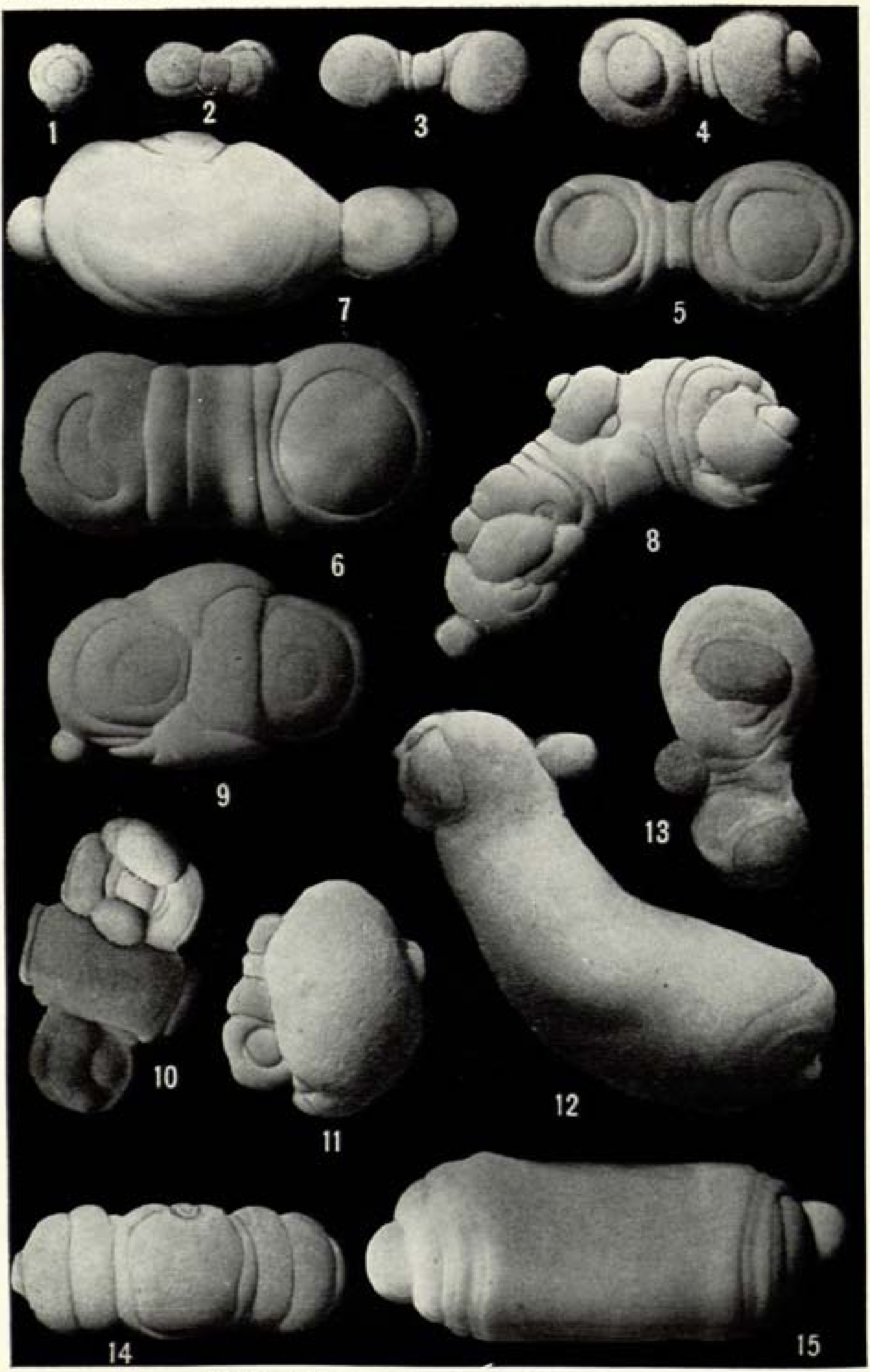
DEVELOPMENT OF LOESSPÜPPCHEN TYPE OF CONCRETIONS

(See explanation of plates, p. 275.)



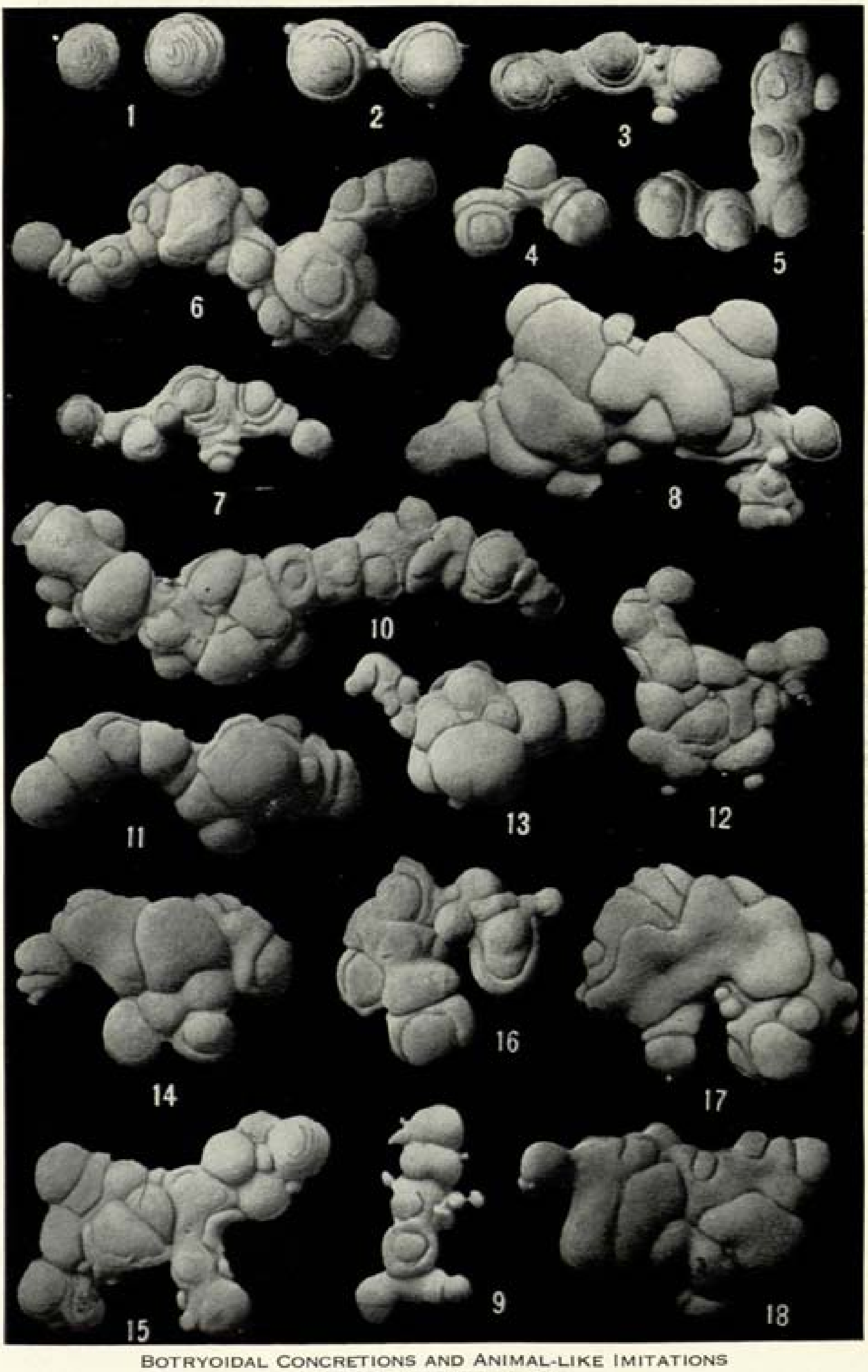
DISKLIKE CONCRETIONS

(See explanation of plates, p. 275.)



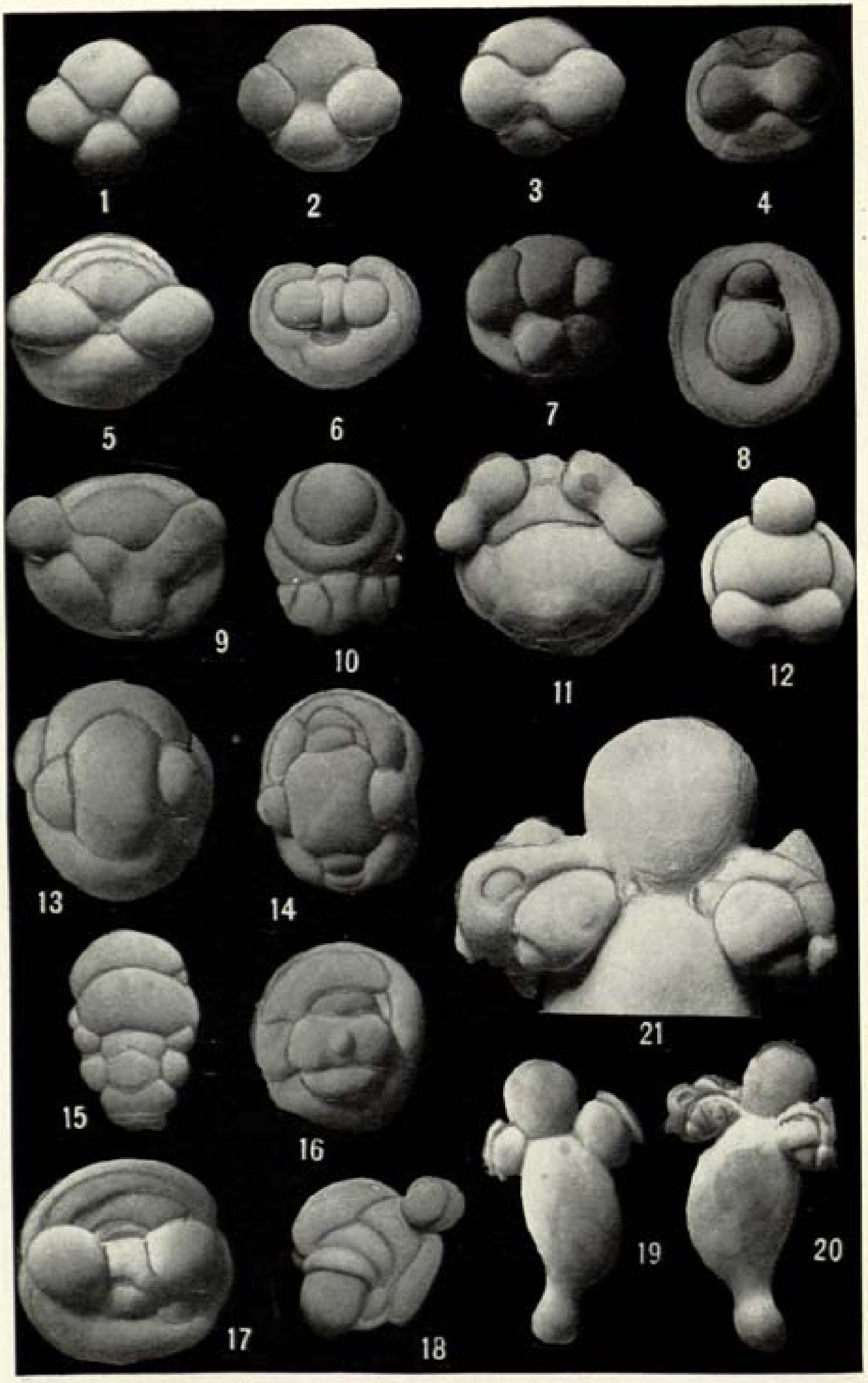
DUMBBELL CONCRETIONS AND MODIFICATIONS

(See explanation of plates, p. 276.)



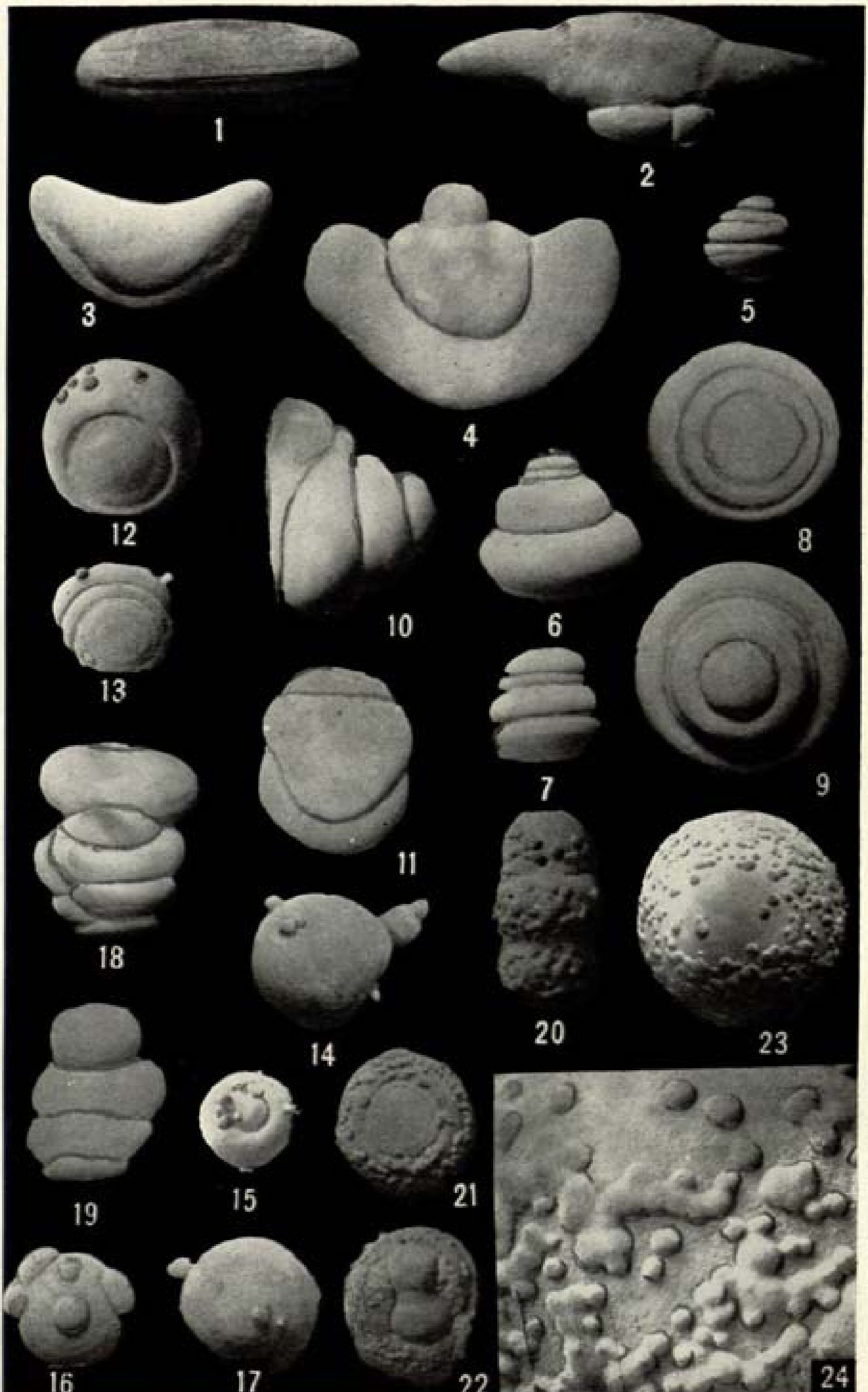
BOTRYOIDAL CONCRETIONS AND ANIMAL-LIKE IMITATIONS

(See explanation of plates, p. 276.)



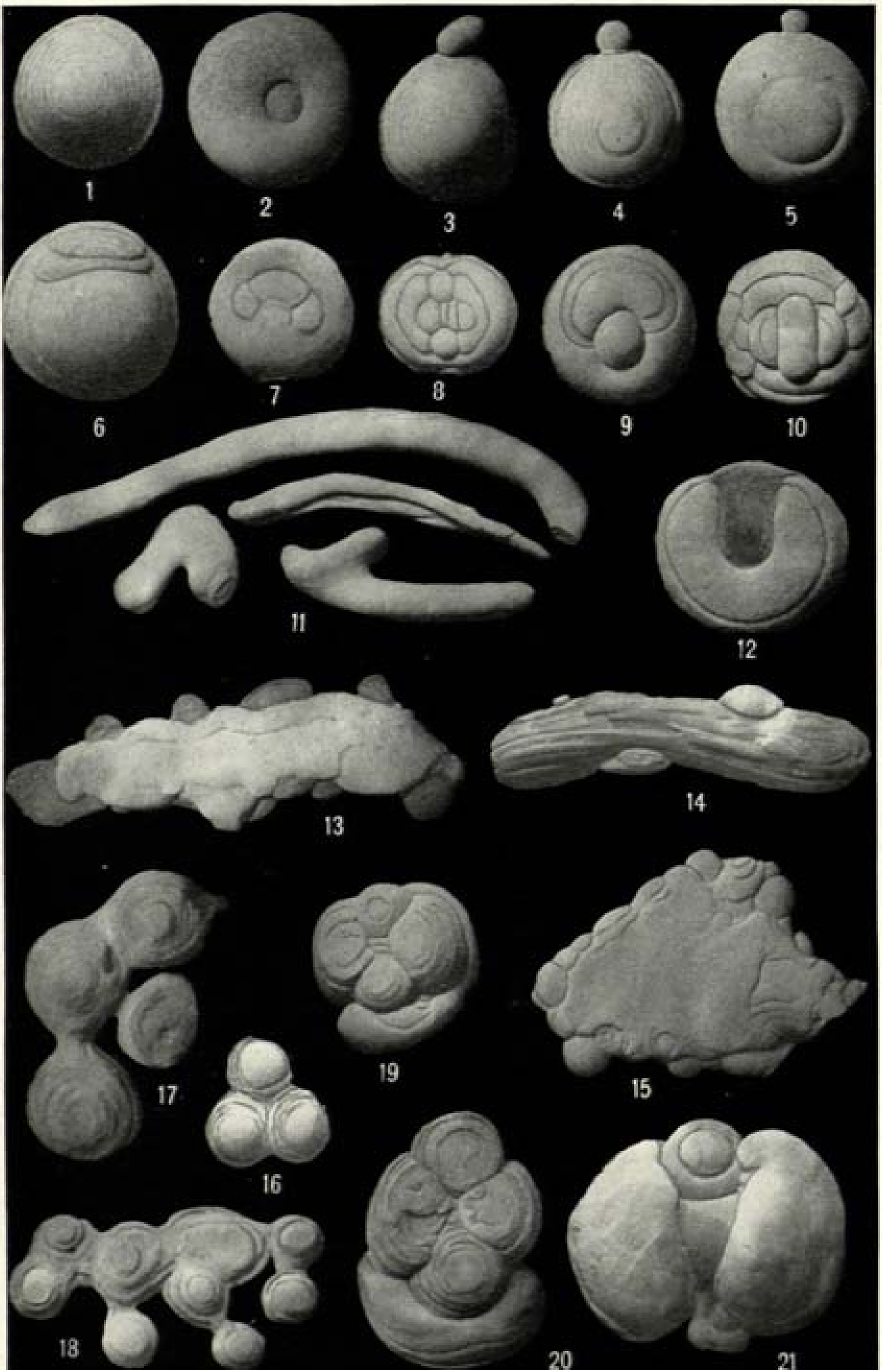
CONCRETIONS IMITATING INSIGNIA, ETC.

(See explanation of plates, p. 276.)



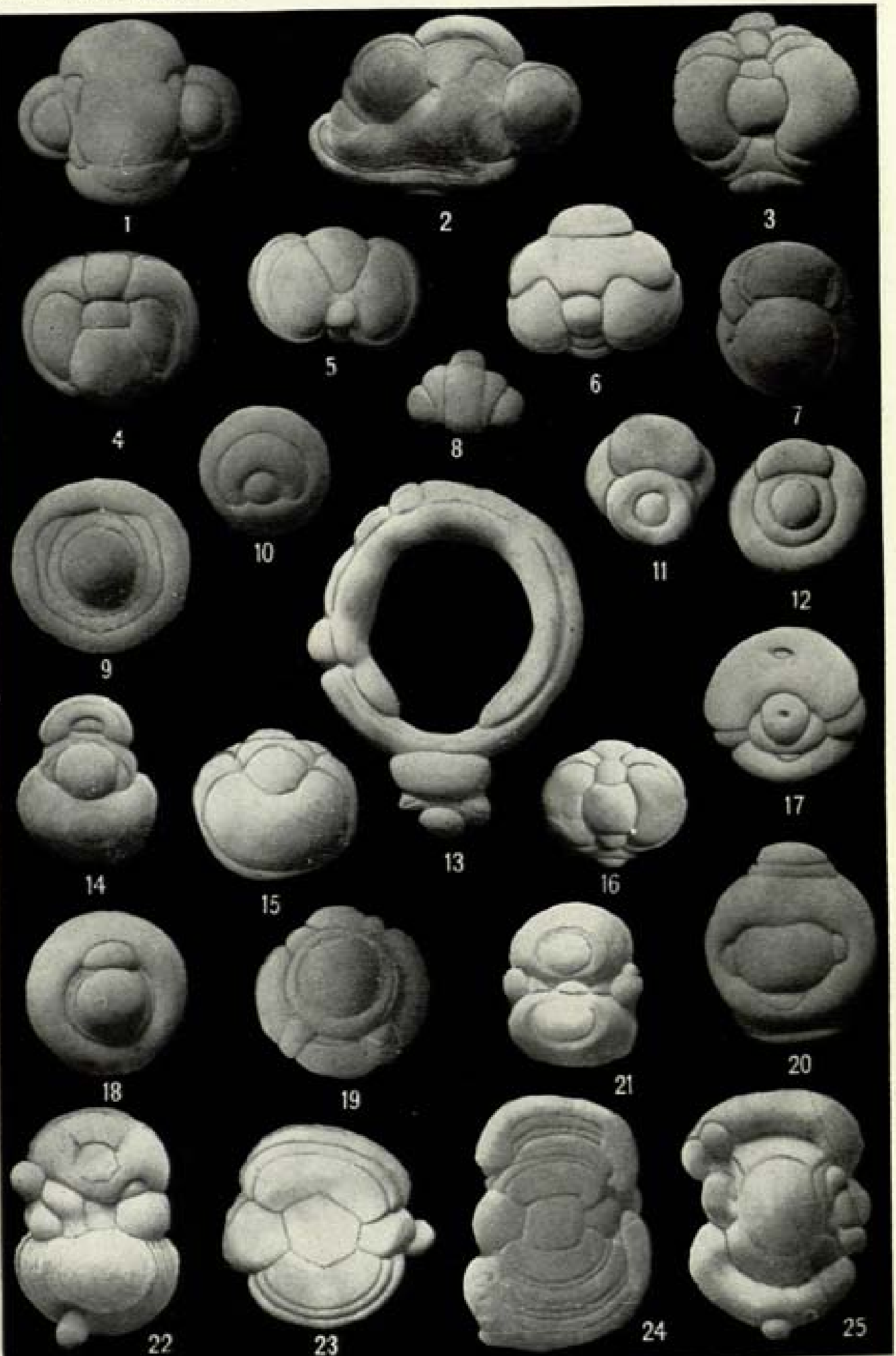
MISCELLANEOUS GROWTH FORMS

(See explanation of plates, p. 276.)



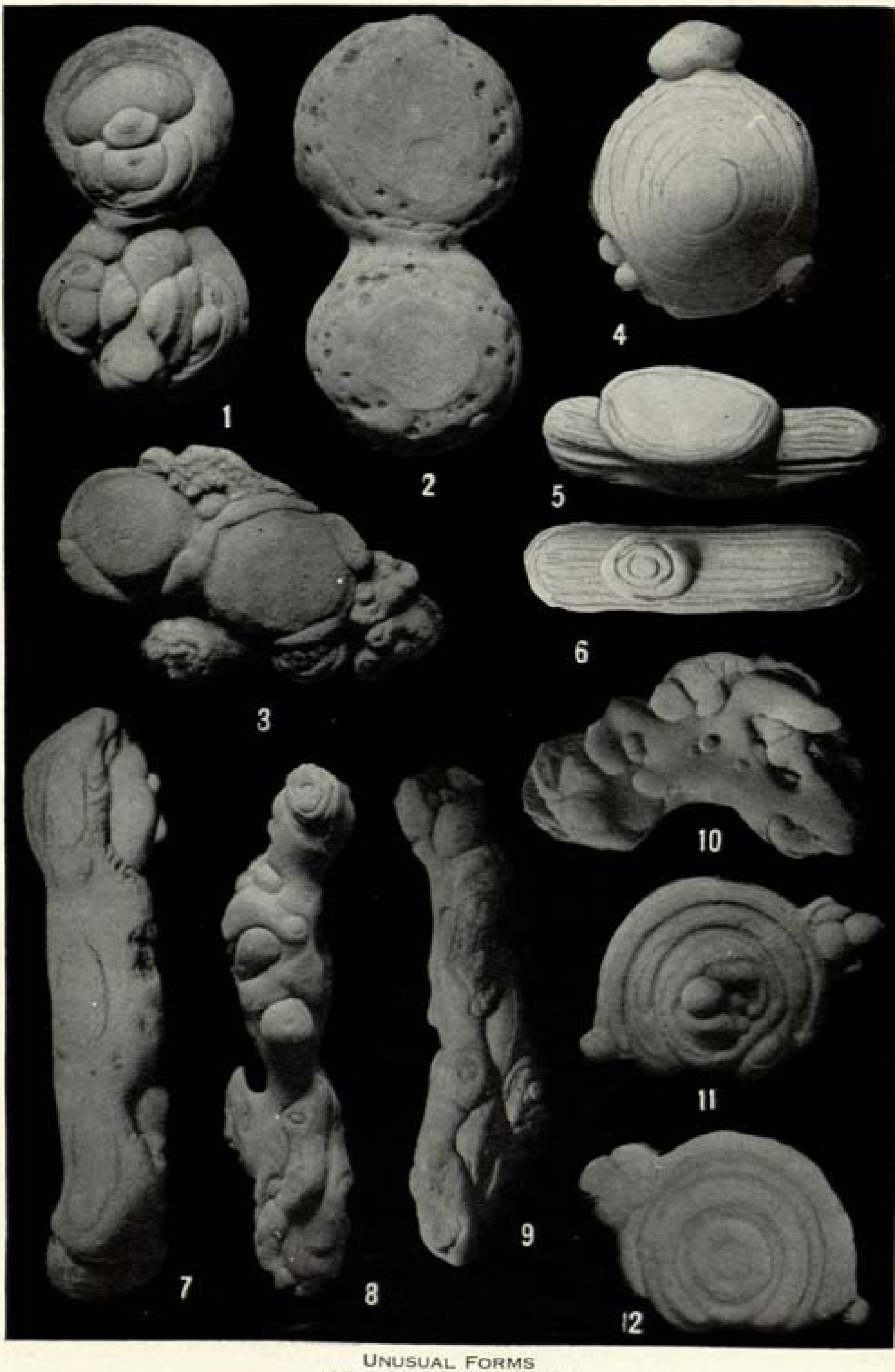
WATCH, HORSESHOE, GLOBULAR, AND OTHER TYPES OF CONCRETIONS

(See explanation of plates, p. 276.)

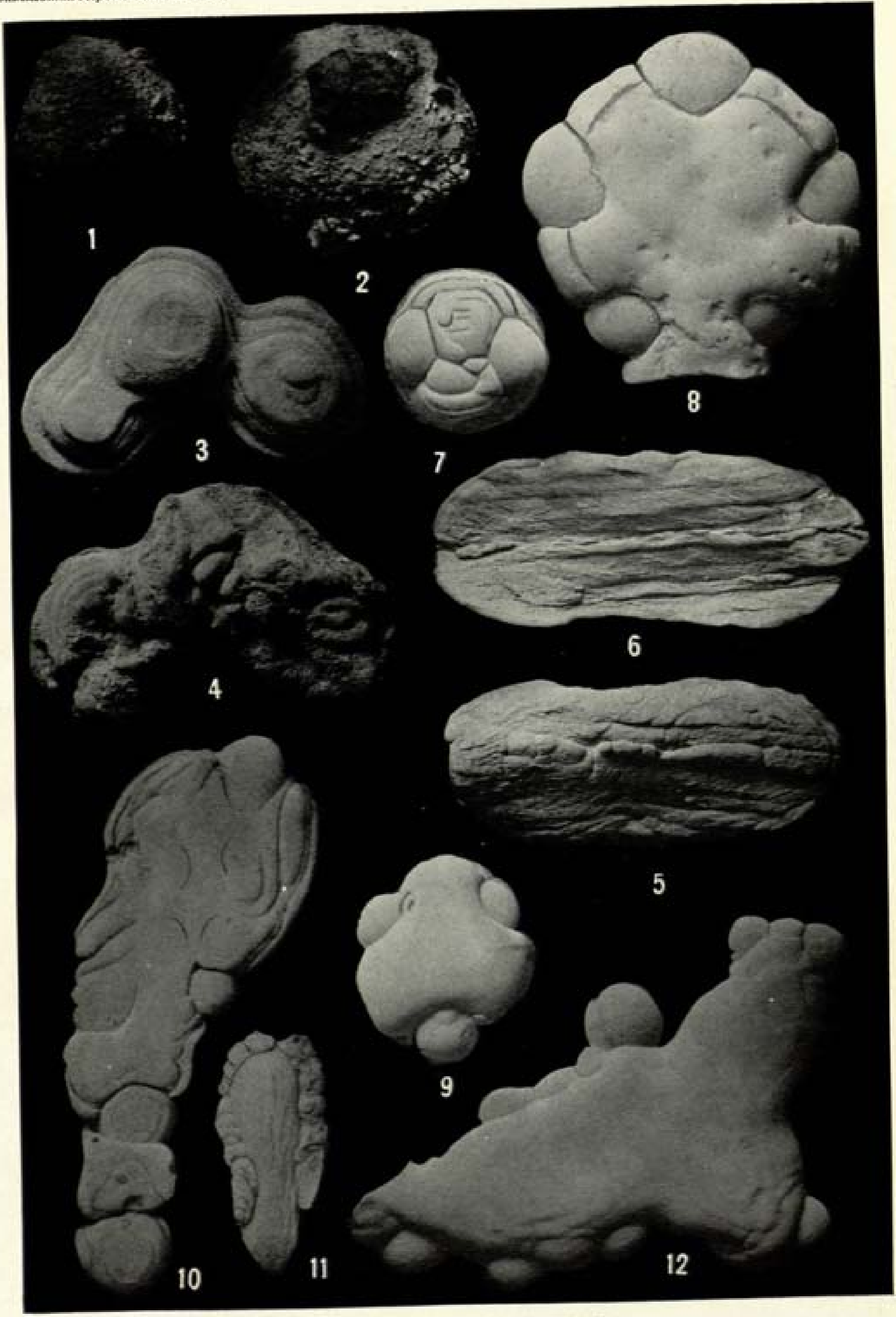


INSIGNIALIKE CONCRETIONS

(See explanation of plates, p. 276.)

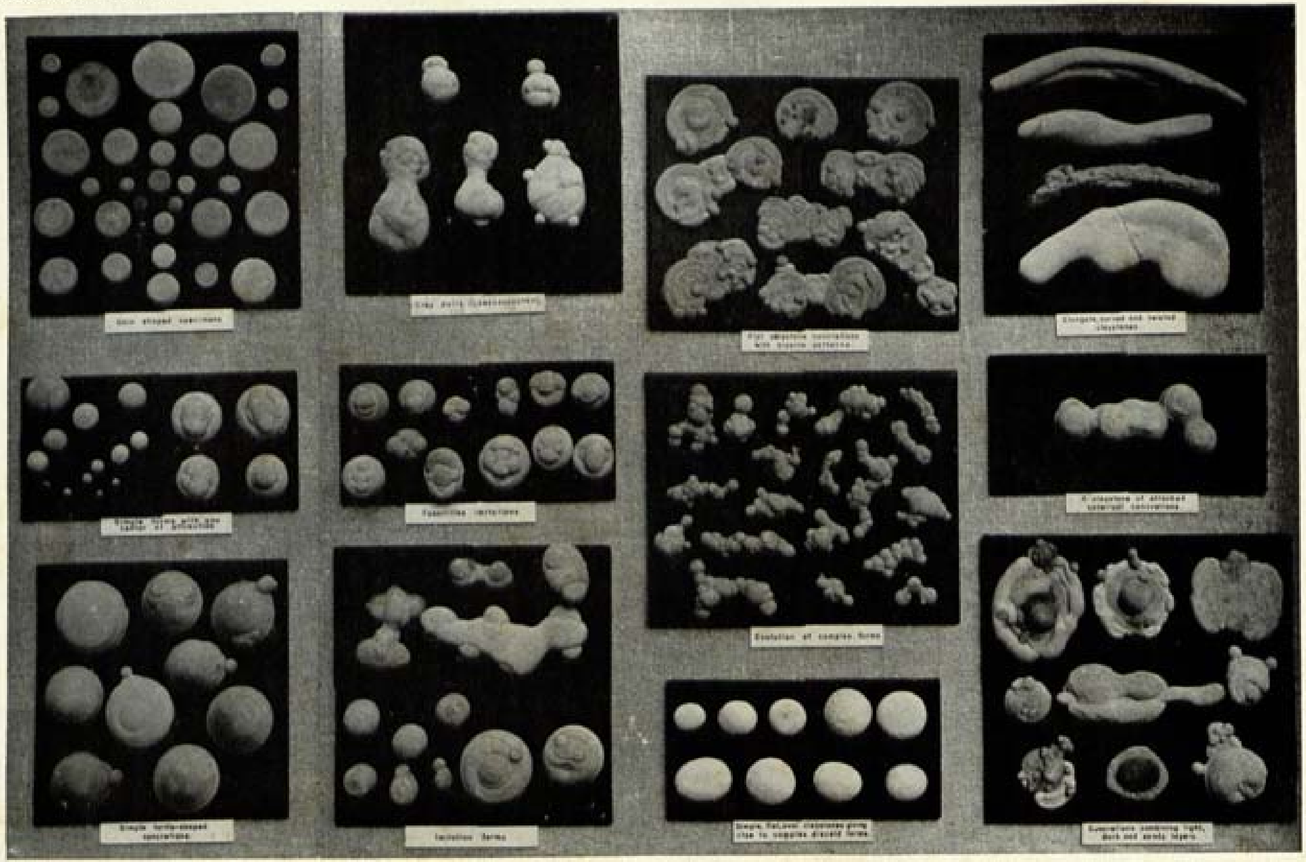


UNUSUAL FORMS
(See explanation of plates, p. 276.)



SAND AND CLAY CONCRETIONS

(See explanation of plates, p. 276.)



VARVED CLAY CONCRETION EXHIBIT, U. S. NATIONAL MUSEUM

(See explanation of plates, p. 276).

distribution of the glacial clay concretions of the northern United States, one must turn back to about the year 23000 B. C., as reckoned by the geologist. At that time the last of the four great ice sheets, marking the Nebraskan, Kansan, Illinoisan, and Wisconsin stages of glacial time which in turn had passed over northern North America, had reached its southernmost limit, roughly indicated today by Long Island and the Ohio and Missouri Rivers. The broken rocks, boulders, mud, and sand pushed up in front of the ice formed the terminal moraine, the conspicuous ridge today marking this southern border. The climate, slowly becoming milder, caused increased melting and a gradual withdrawal northward of the glacial front. The mixture of sand, clay, gravel, and boulders ground up under the ice cap, now becoming exposed, formed the surface deposit known as till or boulder clay.

Water flowing from beneath the ice sheet removed the finer clay material spreading it out on the plains to the south, where evaporation soon dried it ready for distribution by the winds as dust. The result was the loess, a rock term originally applied to the fine, yellowish-gray loam of the Rhine Valley but now recognized in many other parts of the world. Everywhere the loess is characterized by its fertility and by the vertical exposure of the outcrops when cut into because roots of vegetation hold the deposits together. The loess of China, the most extensive deposits in the world, originated in the dust carried by the winds from the Gobi Desert eastward and deposited as soils of such high fertility that thousands of years of cultivation have failed to exhaust them. In northern Europe similar deposits have accumulated in which special forms of doll-like concretions, known in Germany as loesspüppchen, loesskindel, loessmännchen, etc., were developed. Similar concretionary bodies characterize the loess in the United States and China.

Returning to North America, several lobes of the ice-cap front now slowly melted, leaving bodies of water in their wake which ultimately became the Great Lakes of today. South and east of this lobed area, smaller temporary fresh and brackish bodies of standing water formed from time to time owing to the damming of the melting glacial waters against the terminal moraine and other obstructions. In these lakes and ponds another type of glacial deposit, laminated clays, formed under the following conditions, giving rise in time to the particular kind of clay concretions described in this paper. In the summer, the time of active melting, abundant waters emerging from the glacier carried sand, silt, and mud particles, usually light-colored, to these lake bottoms where they settled in a single layer. With the coming of winter, when melting ceased, there was no further deposition except a thin layer of minute clay particles, normally dark-colored, which had been held in suspension in the lake water throughout the previous summer by breezes and currents. Thus, as described by the Swedish geologist DeGeer, every year was marked by two distinct layers, a summer one of light-colored, coarse material, and a winter one of finer consistency and darker color. These two together, often less than a centimeter in thickness, form a distinct band, technically called a varve, from the Swedish word meaning "layer." Since each varve registers a single year's accumulation, the entire number developed in all these lake deposits, if duplication is avoided, will approximate the sum total of years occupied by the latest retreat of the ice cap. In other words, varves, like the growth rings in trees, give a record of geological time in actual years. Hitherto this figure, the time required for the last glacial retreat, had been judged by the amount of recession by waterfalls, like the classic example of the Falls of St. Anthony in the Mississippi River and also Niagara Falls, but varve

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the lake water caused abundant calcium carbonate precipitation and an increased quantity of floating microscopic organisms. The heavy carbonate sank to the bottom, forming the white layer. Later subsidence of the dark organic material, usually in the wintertime, resulted in the dark band of the varve.

Most concretions are collected more for their unique shapes than for their geologic interest. It is rare to find specimens in collectors' cabinets labeled with any information other than their geographic locality, if even that be given. The exact geologic formation and other information of occurrence in the field must accompany all examples if they are to be useful in scientific study. The variety of forms they assume, their different compositions, their occurrence in most all types of rocks, and the conditions of origin whether primary or secondary, are all factors which, if carefully studied, may lead to important scientific results. To the economic geologist concretions should be of interest as a source of minerals or ores brought together through their segregation properties. Many of them in certain sedimentary rocks have formed about well-preserved fossils making them of special interest to the paleontologist. The strange and often bizarre designs assumed by the varved clay examples should be an inspiration to the artistic world.

The experience of collectors has shown that individual beds or portions of outcrops develop almost identical forms, just as the individual strata of sedimentary rocks carry their own characteristic fossils by which they can be identified from place to place. However, in the case of concretions this similarity is due to their identical conditions of origin and does not depend upon time differences as in the fossils. For example, the National Museum has an extensive collection of Croton Point, N. Y., concretions from sandy beds above the varved clays, which shows no symmetrical specimens and an almost complete absence of the characteristic flat forms. Most of these specimens are greatly distorted, but in spite of this some indicate an attempt to assume the symmetrical patterns of the varved clay examples.

In the present paper the writer has studied this exceptionally complete lot of concretions as if it were a collection of fossils from some specific geological horizon and locality, in this case the Post-Wisconsin (Champlain) varved clay of New England. The photographs were prepared to illustrate the trends of concretion growth and the individual stages of each, in place of the genera and species of the organic world. The plates, therefore, can be used for correlative purposes when studies of concretions from other geological formations and of different origins are undertaken.

In spite of their diverse forms these specimens can be roughly classified into the following groups, omitting some irregular examples noted in the plate explanations. This outline differs from Professor Hitchcock's classification of a century ago in employing the evolution of their shapes as a basis, but it is evident that any classification of such variable objects is only a matter of personal opinion.

Generalized Classification of Ryegate Glacial Varved Clay Concretions

1. Simple, bulletlike forms growing into loesspüppchen (pl. 2).
2. Thin, flat, smooth disks with faint circular ornament, occurring in narrow layers of pervious clay (pl. 3, figs. 1–4).
3. Coin-shaped disks with smooth base and flattened confluent lobes on upper side (pl. 3, figs. 5–11).
4. Hemispherical, smooth specimens in beds thick enough to allow growth in all directions (pl. 3, figs. 12, 13).
5. Thin disks becoming confluent laterally with circular ornament on both sides and small lobes on upper (pl. 3, figs. 14–19).
6. Bulletlike forms uniting and developing into flattened dumbell shapes (pl. 4).
7. Grapelike or botryoidal growths uniting into bulbous, twisted structures simulating animal and other forms (pl. 5).

8. Oval examples with smooth base and regularly lobed upper surface (pl. 6).
9. Turban-shaped concretions with smooth base and concentric lobes on upper surface (pl. 7, figs. 5–11), etc.
10. Globular forms with surface marked by minute nodes (pl. 7, figs. 12–17, 20–24).
11. Watch-shaped examples with terminal node and concentric ornamentation on upper surface (pl. 8, figs. 1–10).
12. Elongate, twisted, and bent specimens (pl. 8, fig. 11).
13. Convoluted globules joined at their extremities (pl. 8, figs. 16–20).
14. Circular to oval concretions with flat base marked by growth lines and lobed upper surface giving artistic effects (pl. 9).

The term varved clays has been extended by geologists to include all seasonally deposited clays, and so in future studies, ocean deposits of this nature, those of fresh-water lakes and other types not connected with glacial action must be distinguished. Glacial phenomena such as moraines, till, and scratched boulders will always be found in the vicinity of glacial varved clays, as a check on their identification. The writer now believes that the study of concretions of all kinds and ages promises scientific results much out of proportion to what is thought and known of them today.

Concretion collecting simply as a hobby is recommended as a source of outdoor exercise and good health. Most often the layers yielding the most interesting claystones crop out along river beds. Here a boat and pair of boots are excellent adjuncts to this particular kind of fishing, while a trowel helps in landing the specimens. The student is especially urged to search more ancient glacial clays, for example, the varved deposits of the Proterozoic era over a half billion years ago, those of the close of the Paleozoic 200 million years since, and the Mesozoic 60 million years back in time.

The same great spirit or intelligence that can produce life, manifests itself in the inorganic world in giving rise to these intriguing inanimate objects, claystone concretions.

EXPLANTION OF PLATES

Plate 1

Clay Island at Ryegate, Vt.

Views of several slopes and samples of this mound of glacial varved clay, 75 feet high, which, unless otherwise mentioned, furnished the specimens photographed for illustration of this paper. At the left, a 60° slope showing the laminated, concretion-bearing clays, with a moist, dark-colored layer near the top which could start a landslide. In the center, three edge views of varved clay samples showing concretions restricted to the light-colored (summer) layers. In each case a dark (winter) layer capped the concretions, but in drying it was lost except in the topmost specimen. To the right, view of a 40° slope with Mr. Pringle extracting concretions mainly with his hand trowel. Footholds must be cut to ascend the slope which ordinarily is dry and hard, but slippery and dangerous after a minute or two of rain.

Plate 2

Photographs of a series of claystone concretions, all about ½ natural size, illustrating the development from simple, bulletlike forms (fig. 1), through two joined together by a narrow band (fig. 2), the band increasing in size (figs. 3–5), a flat basal side showing growth lines (fig. 6), and top views (figs. 7–15) showing the band merging with the larger end and the smaller extremity developing the usual three-noded type, this combination usually classed as loesspüppchen. A double-headed form with a constricted basal node is shown in figure 16, while figure 17 represents a specimen formed of dark material with a cover of the lighter-colored clay, illustrating interrupted development.

Plate 3

Specimens of thin, disklike concretions, about ⅔ natural size, formed in thin layers of clay. Thin, smooth, flat disks (figs. 1–4) consisting of one or several layers which split apart upon frost action. No. 1 shows two such layers partly separated, and No. 3 the faint concentric lines indicating growth about a center. Figures 5–11, coinlike concretions arising from small, thin disks (figs. 5, 6) which are smooth on the bottom but are progressively ornamented by flattened confluent lobes on top as more layers are added (figs. 7–11). Figures 12 and 13, smooth, hemispherical concretions with rounded edges and nodes of growth added at the sides, formed in thicker layers of the clay. Figures 14 and 15, thin, disklike forms merged together laterally, exhibiting the surface ornamentation (fig. 14), and a view through the center when split apart. Figures 16–19, a series of thin, platelike specimens illus-

trating the simplest form (fig. 16), then the upper surface of a similar example with central nodes developed (fig. 17), next, two such structures joined by a symmetrical keystonelike arch (fig. 18), and finally three united in a row (fig. 19).

Plate 4

A series of dumbbell concretions with modifications, about ⅗ natural size. The simple, bulletlike form (fig. 1) either joins with a similar one or develops a new growth connected by a band (figs. 2–6). Sometimes the end nodes become curiously modified (figs. 7, 8), or the middle band may become overdeveloped (figs. 9, 10). In figure 11 a small typical form is almost engulfed by a secondary smooth clay deposit. Further modifications are shown in figures 12, 14, and 15, while in figure 13 the primary form here composed of dark clay has been largely covered by a broad deposit of lighter-colored clay.

Plate 5

A series of botryoidal or grapelike forms, all about ⅗ natural size, in which the simplest concretion is roughly rounded with concentric growth lines (fig. 1), becomes joined to similar associated forms by narrow strands (figs. 2, 3), which are absorbed with increased growth. Additional nodes are added at various angles (figs. 4–7), until a series of strange, animal imitative forms develops (figs. 8–18). The reader can possibly imagine a Bactrian camel, sea serpent, hen, ant eater, dog, and dinosaur among this assemblage.

Plate 6

Insignia imitations (all natural size except figs. 6, 8, 13–18, which are × ⅗) illustrating the regularity of lobe development on top side (figs. 1–17) with bottoms faintly marked, an insect imitation (fig. 18), and top and bottom views of a tadpolelike concretion (figs. 19–21, Schoharie, N.Y.). (Fig. 21, × 2.)

Plate 7

Photographs, about ¾ natural size, of various simulating concretionary specimens. Capsulelike, etc. (figs. 1–4), turban-shaped (figs. 5–9), side and bottom views of the same turban-shaped form (figs. 10, 11), globular bodies with minute nodes (figs. 12–17), top and bottom views of a specimen with parallel lobes (figs. 18, 19), globular forms with small surface nodes (figs. 20–23), and enlarged view showing increase by confluence of nodes (fig. 24).

Plate 8

Various types of concretion growth (about × ½ unless otherwise stated). Watch-shaped forms (figs. 1, 2), with terminal node (figs. 3–5), and a series (figs. 6–10) showing development of upper surface ornamentation, four grooved, twisted, and bent forms (fig. 11, longest specimen 14 inches), a simple type (fig. 12) of a dark concretion upon which lighter-colored layers have been arranged horseshoelike, a flat, elongate, dark example with deposit of light-colored layer (fig. 13), an elongate twisted form (fig. 14), and a flat specimen with scalloped edges overlain by smooth growth (fig. 15), convoluted globules joined in increasing complexity (figs. 16–20), and a dumbbell form partly covered by large, smooth, lateral lobes (fig. 21).

Plate 9

Imitative forms of claystones, all × ½ except figure 13, which is × ⅓. Trilobitelike specimens simulating a perfect head and a distorted one (figs. 1–2), 3-lobed examples (figs. 3–8), symmetrically lobed forms (figs. 9–12), a centrally perforated ring like a door knocker (fig. 13, from Rutland, Vt.), various types arranged around a central node (figs. 14–21), and specimens with flat base (figs. 23, 24), showing growth of lobes on medallionlike upper surface (figs. 22, 25).

Plate 10

Unusual forms of clay concretions, all ½ natural size. Top and bottom sides of two specimens, with corresponding sides identical in each (figs. 1, 2); tops of four diverse imitative forms (figs. 3–6); edge views of elongate, twisted forms, the first showing an unusual profile (figs. 7–9); an example with confluent surface lobes (fig. 10); thin, shell-like imitation, top and bottom views (figs. 11, 12).

Plate 11

Photographs of sand and clay concretions, ½ natural size. Two concretions composed of sand and rock fragments cemented by calcite (figs. 1, 2); top and bottom of a trinodate specimen symmetrical on the upper side, formed in clay and distorted on the lower side which rested in an underlying sand layer (figs. 3, 4); top and bottom of a thin, angular form (figs. 5, 6) showing attempt at symmetry on upper face (fig. 5); thin types of symmetrically lobated forms (figs. 7–9); three thin, flat imitative forms (figs. 10–12).

Plate 12

A portion of the Ryegate, Vt., varved-clay concretion exhibit in the National Museum hall of physical geology. This does not include any of the type specimens illustrated on plates 1 to 11.

Algal Pillars Miscalled Geyser Cones[1]

By Roland W. Brown, *Geological Survey, U. S. Department of the Interior*

[With 8 plates]

The unsuspecting traveler on the less-frequented trails in the region northwest of Rock Springs and Green River, Wyo., may occasionally be surprised and mystified by encountering what seem to be either fossil stumps or rounded rock columns erected by a prehistoric race. At a number of localities these protrude through the strata as large conical or cylindrical pillars, standing singly or in small groups (pls. 1, 2). Local collectors have dug out many of them, which they, as well as some geologists, have tentatviely called geyser cones, that is, vertical, hollow structures resembling those developed at the vents of hot springs and geysers. Superficially, this identification has some plausibility because many of these pillars are more or less hollow and cross sections of them display layered deposits somewhat like those present in most geyser cones. However, here, as elsewhere, appearances are deceptive, things are not what they seem, and hasty conclusions based on only a few of the most obvious features of the circumstantial evidence must be revised. Herewith are the details of my own adventures and observations regarding these objects.

During field work in the summer of 1946, I arrived one day at Green River, Wyo., and became acquainted with William Hutton, Jr., an enthusiastic collector. The elaborate "den" in the basement of his home contains an exhibit of his large collection of minerals, rocks, fossils, and archeological relics. Attracting immediate attention is the wall of the spectacular fireplace, which is constructed largely of fossil wood, but mixed with the wood are sections of "geyser cones." These, together with the hundred or more additional specimens around the outside of the house and along the walks in the yard, aroused my curiosity intensely. Noting this, Mr. Hutton volunteered to accompany me to a nearby locality where I could see "geyser cones" in place and observe attendant geologic conditions. Thus, Sunday morning, September 15, found us in Whisky Basin, a local part of the larger Bridger Basin. The locality is a high, open valley area surrounded by low, badland hills, about 27 miles northwest of Green River and 12 miles northeast of Granger (pls. 1, 2). A locality similar to this, but not visited by me, is 30 miles west of Whisky Basin and 6 to 8 miles southwest of Opal, Wyo., where G. P. Merrill, in 1903, collected many specimens for the United States National Museum. Sections of some of these are here illustrated as noted in the legends.

The rock strata of the valley floor and surrounding hills are nearly horizontal, variegated, but chiefly greenish sands and clays having a heavy admixture of volcanic ash. There are occasional lenses of ironstone and carbonaceous shale. These strata lie

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along the axis of the Bridger Basin, which is a broad, shallow rock-trough or syncline between the Wind River Range of Wyoming and the Uinta Mountains of Utah. Eocene sedimentary rocks dip gently from all sides toward this northeast-southwest trending axis. Along the central portion of the basin the uppermost rock exposures are the drab, greenish, or varicolored strata of the Bridger formation. Beneath these rocks are the gray to dark shales that weather white, and the grayish-yellow sandstones of the Green River formation. These strata, in turn, overlie the reddish and greenish Wasatch formation, whose outcrops, except for a few small gaps, completely encircle the Bridger Basin with a striking zone of color. The Green River, which drains the basin, originates in large part on the west slope of the Wind River Range and flows southwestward through colorful badlands in the Wasatch formation to Labarge, Wyo. There it turns southeastward and in a 65-mile course through Green River and Bridger strata bisects the basin before veering south near Green River toward the Uinta Mountains.

The landscape of the Bridger Basin, carved out by the Green River and its tributaries, is at a general elevation of 7,000 feet and comprises open grass and sagebrush plains, broad, cottonwood-lined valleys enclosed by low hills, and occasional mesas or buttes with precipitous slopes or desolate, dissected badland borders.

When found undamaged and standing upright in the sands and shales of the Green River and Bridger formations, the pillars are usually well rounded at the top and sides, are without an orifice of any kind, and are gray to brownish in color. Casually observed they look like columnar concretions or stumps of fossil wood whose tops were rounded by weathering. They may extend into the ground for several feet and their more or less irregular, sometimes spreading, flat bottoms rest on shale without any evidence underneath of a vent, such as should be expected were they true geyser cones. Moreover, the ground and bedrock in their immediate vicinity show no evidence of hot-spring action, such as tufaceous or sintery sheet and terrace deposits. The landscape of the Bridger Basin is developed in fresh-water strata, which, at the sites I visited, are not faulted, and the nearest outcrops of igneous rock or surface evidence of volcanic activity are 30 miles distant. Therefore, a visible, possible cause or source of hot waters, and fractured rocks permitting their emergence from subterranean depths, is not present in the Whisky Basin area.

Let us examine these pillars more closely. Their outer surface is relatively smooth but may be warty or tuberculated and may be broken as a result of spalling, the curved, shelly fragments strewing the ground in the vicinity. Roughly transverse fractures or joints are sometimes present, causing the specimens to disintegrate into thick, millstonelike sections (pl. 2, fig. 1). Inside, a typical cross section (pl. 3, fig. 1; pl. 5, fig. 2) shows well-marked inner and outer zones distinguished by color, minerals, and the "growth" lines indicating the direction in which the zones "grew" by the addition of successive layers of mineral matter.

The inner zone may consist of an irregular opening lined with translucent or banded chalcedony (agate) (pl. 5, fig. 2), sometimes with quartz crystals projecting inward (pl. 3, fig. 1), thus simulating a geode. The center, however, may be completely filled with chalcedony and quartz, or it may, in addition, have crystals of calcite, or may be composed entirely of calcite. Relatively rarely it may contain a piece of fossil wood (pl. 7). Clearly, the beginning of chalcedony banding was at the outermost boundary of chalcedony (pl. 3, fig. 1; pl. 5, fig. 2) and proceeded inwardly in successive, parallel layers or bands until quartz or calcite crystals ended this phase of

mineralization with the partial or complete filling of what had obviously been a cavity, that is, a space unfilled by mineral or organic matter for some time prior to the entrance of the solutions from which the chalcedony, quartz, and calcite were derived.

The outer zone, sometimes 20 cm. thick, extends from the outer boundary of the chalcedony zone to the periphery of the pillar. It consists of many thin, somewhat undulating laminae or layers of lime ($CaCO_3$) deposited one upon the other (pl. 4), thus causing "growth" of the zone in the direction away from the center, in contrast with the development of the chalcedony zone, which was toward the center of the pillar. The layers are fairly uniform in thickness and they are the result of a coalescence of materials laid upon closely spaced centers of origin in such fashion as to cause a succession of small, outwardly bulging arcs (pl. 3, fig. 2) around the pillar. All the layers with their minute arcs and intervening depressions unite in giving this zone a somewhat spongy appearance and, when examined with a hand lens, show that the zone is neither a cross section of fossil wood nor a section of a concretion with chemical rings or bands. Rather, it is quite evident that small, spherical algae, the molds of which are still visible between the layers (pl. 4), were involved in the deposition of this zone.

The outer zone of these pillars is, therefore, identical in origin with the deposits comprising the reefs, algal pebbles, and coatings around fossil wood found in the shore phases of the Green River formation. Those incrustations were attributed by Bradley (1929) chiefly to the activity of the alga *Chlorellopsis coloniata*. Johnson (1937) referred similar but smaller reef-building algae from the Oligocene lakes of South Park, Colo., to *Oncobyrsella coloradensis*. The large, encrusted logs described by Bradley (p. 210) simulate sections of the pillars from Whisky Basin, with the exception that silicified wood, instead of chalcedony, is the material of their inner zones. As these logs are usually found in prostrate position with much of the wood intact they have never presented any special difficulties as regards explanation of their origin.

In many of the upright pillars from the Bridger Basin, the outer limy zone is more or less silicified, the silica filling the irregular pores and crevices in the spongy calcium carbonate or replacing it completely. It is clear, therefore, that this impregnation by silica and filling of the center by banded chalcedony and quartz occurred subsequently to the attainment of full outward size by the pillars, that is, after algal activity ceased. One section (pl. 6, fig. 2) bearing on this point is especially pertinent. After a considerable thickness of lime had been deposited, the pillar toppled over or was thrown over so that the side on which it fell was bashed in, as shown by the conspicuous "fault" line, angles, and pieces of broken algal segments within the enclosure. Further, the chalcedony "growth" lines, conforming to the angles and paralleling the outlines of the broken segments, clearly indicate that the emplacement and banding of the silica was subsequent to the completion of the algal deposit. In some instances the innermost laminae of the algal zone appear to have suffered some solution or disintegration before silicification began. Here it should be stated that, although a general pattern of development can be described as applying to all the pillars, each specimen has individual peculiarities caused by variations in the environmental conditions under which it originated. By paying too much attention to these minor though interesting details and effects, it is quite possible to lose sight of the main process.

Essentially, the chemistry of the process by which algae cause deposition of lime from waters charged with that substance is regarded as simple, namely, that as these aquatic algae

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live, grow, and multiply they remove carbon dioxide from the water during photosynthesis. As the lime dissolved in the water is in the form of the unstable bicarbonate, $H_2Ca(CO_3)_2$, the removal from the water of carbon dioxide, which helps to keep the bicarbonate in solution, causes the reversion of the bicarbonate to the insoluble carbonate, which is precipitated, and water. $H_2Ca(CO_3)_2 - 2CO_2 = CaCO_3 + H_2O$. This process is the same for both cold and hot waters, with the exception that perhaps evaporation and release of pressure may play a larger part in freeing hot waters of carbon dioxide. As the solubility of carbon dioxide in water decreases with increase of temperature, it would seem that the warming of lake waters in summer, the optimum season of algal activity, would assist the algae in precipitating lime. The visitor at Mammoth Hot Springs in Yellowstone National Park, where lime is deposited as travertine, and in the Geyser Basin, where siliceous sinter or geyserite is deposited, will note the colors displayed and will understand that many of these are principally caused by different species of algae (Weed, 1889). Both here and at the hot springs at Thermopolis, Wyo., and elsewhere, filaments of algae can be seen in the hot waters. That these algae may not have as much to do with the precipitation of lime as Weed assumed seems to be proved from the observations and experiments of Allen (1934). The rate of deposition of travertine from hot springs is rapid, but variable, sometimes averaging 20 cm. per year. Howe (1932, p. 61), describing "water biscuits," quotes Pollock as estimating that blue-green algae may deposit marl at the rate of one foot in 75 years. How long it took to precipitate 20 cm. on a Whisky Basin pillar is indeterminate, but must probably be reckoned in decades, perhaps hundreds of years.

As the lime-precipitating algae, like all chlorophyll-bearing plants, require sunlight, it follows that the waters in which the pillars of Whisky Basin developed were shallow and seasonally, at least, relatively clear. It is considered that fresh-water algae cannot function well in depths of more than 10 m. (Cloud, 1942, p. 371). This accords with the aspect of the sediments of the Green River and Bridger formations, which were deposited on flood plains that included sloughs, marshes, ponds, and lakes. These waters were the habitat of many kinds of fishes, turtles, and crocodiles. The swamps and adjacent plains supported ferns, palms, laurels, elms, beans, and many other plants indicative of a warm temperate climate; and the land animals included birds, rodents, insectivores, carnivores, and large herbivorous odd-toed titanotheres. As time passed, the meandering streams of the Bridger plains doubtless on occasion shifted their channels or changed courses, making new ponds and marshes and filling old ones with sediments. Trees or shrubs inundated by these processes would in time be killed and become snags along the shore.

Such, then, are the basic facts that can be read from the Whisky Basin pillars themselves and their geologic setting. Can these facts now be arranged in orderly sequence to explain satisfactorily how the pillars originated?

The clue to the solution of this problem and beginning of its unraveling patently lies in the irregular boundary between the inner and outer zones of the specimens—the surface on which the algae first settled and deposited the first lime. What was that surface? It had to be a surface on something substantial, relatively slender, and upright, for it is obvious that such algae could not start on nothing and build up a long, thick, relatively uniform cylinder of lime. Further, this support, after serving as scaffolding for the algae, had to disappear in whole or in part so that silica could fill the space it vacated and form what is now the inner zone of the structure. The only substance that fulfills these requirements, under all the conditions stated,

is wood—the upright, more or less decayed stems, trunks, stumps, and snags of trees or shrubs killed by drowning where they stood in an area recently flooded or ponded. The irregular contours with jagged lobes and odd angles of the boundary between the inner silica zone and the outer lime zone of many specimens indicate that most of the wood had already lost its bark and had undergone considerable decay and erosion before lime deposition on it began. Such deterioration occurs when wood is submerged in shallow, circulating waters where bacteria, fungi, and other destructive agents are free to act and are not inhibited by antiseptic conditions like those prevailing in peat bogs and the stagnant bottoms of deep lakes. The tops of submerged stumps tend to become more or less ragged to blunt-pointed. Consequently the first layers of algal lime covering such tops appear somewhat disrupted or incoherent. Eventually, however, the limy layers on the sides of the pillars became homogeneous with those covering the tops (pl. 2, fig. 3; pl. 3, fig. 2). The fact that the tops of the upright pillars are entire and continuous, without any evidence whatsoever of having had an orifice, is further proof that the pillars are not geyser cones. Furthermore, the laminae of the pillars viewed in lengthwise sections (pl. 3, fig. 2; pl. 8, fig. 2) are in effect cylinders within cylinders with rounded to conical caps, whereas the layers in true geyser pillars are parts of cones within cones like the cups in a stack of paper drinking cups (pl. 8, fig. 1). While these layers were being added one after another, worms and insect larvae, living in tubes or cases (pl. 2, fig. 3; pl. 3; pl. 7, fig. 2; pl. 8, fig. 3), infested the outside of the growing pillars, crawling over them or attaching themselves to the surface. After emergence of the adults, such as caddis flies or midges, the cases and tubes were abandoned, and these became new centers for algal deposits. Most of the empty cases and tubes filled with calcareous sand and ostracodes (pl. 8, fig. 3), or, if left empty, with calcite or chalcedony as a result of later mineralization.

As the tree stumps and snags, submerged in the ponds and lakes, were rooted in bottom mud and sand, no algal deposits could form over the buried portions. Therefore, the roots and those parts above the mud-line, now encased in algal lime, would continue to decay until, in most instances, all the wood was destroyed. Moreover, no algae could deposit lime in the water-filled spaces where the wood had been because algae, requiring sunlight, could not live in those dark chambers. Also, it seems that neither sand nor mud could seep into those cavities.

Eventually the ponded condition of prehistoric Whisky Basin changed. The ponds and lakes disappeared by being filled with sediments, thus ending the algal phase of deposition, if it had not already ceased, and burying the algal pillars. Several hundreds of feet of Bridger strata, which in neighboring areas yield many fossil animal remains, finally covered the site of the algal deposits, approximately 40 million years ago. Then subterranean, circulating waters, percolating through the Bridger strata, which contain much volcanic ash, a rich source of silica, leached out some of the silica and permeated the buried, porous, limy, algal pillars, filling all holes and crevices with the silicifying solutions. In time the pillars and any remaining wood became silicified, but in many instances the silicification was incomplete, leaving hollow centers in the pillars studded with quartz or calcite crystals. I shall not pretend to explain the chemistry of this process.

I have seen only a few specimens from Whisky Basin with remnants of wood left but, unfortunately, have no illustrations of them. Most of the specimens here illustrated (pl. 5, fig. 1; pl. 7, fig. 2; pl. 8, fig. 2) are from the Esmeralda formation (Late Tertiary) about 4 miles west of Tonopah, Nev.

They were collected by John L. James and given to Frank L. Hess, formerly of the United States Bureau of Mines, who made them available to me for study and conferred with me in the preparation of this paper. The specimens are silicified and the wood, which is coniferous, shows evidence of extensive destruction before being covered with algal incrustations. Another specimen (pl. 7, fig. 1) is from a locality near Eden and Farson in the valley of Sandy Creek, 25 miles northeast of Whisky Basin, but from the same Bridger strata. This area is noted for "geyser cones" and fossil wood. The wood of this specimen is dicotyledonous, probably of the sumac family (Anacardiaceae).

During many millions of years the present drainage system evolved in the Bridger Basin, carving low hills and broad valleys out of the Green River and Bridger strata and exposing the long-buried algal pillars. These now remain as monuments marking sites along the shores of the Eocene lakes where timber was submerged, covered with algal deposits, and then, for the most part, destroyed without a trace. It is unlikely, however, that all such pillars originated precisely in the manner just described, for algae could settle on other objects than wood at the bottom of a lake and thus produce variations in the process of pillar and reef building, with subsequent complications.

The hollow "sand trees," recently described by Walker (1948) from San Nicolas and San Miguel Islands off the southwest coast of California, were formed in an entirely different manner, namely, by burial of trees in windblown sand, with subsequent rotting of the trees and mineralization of the peripheral casings by calcite.

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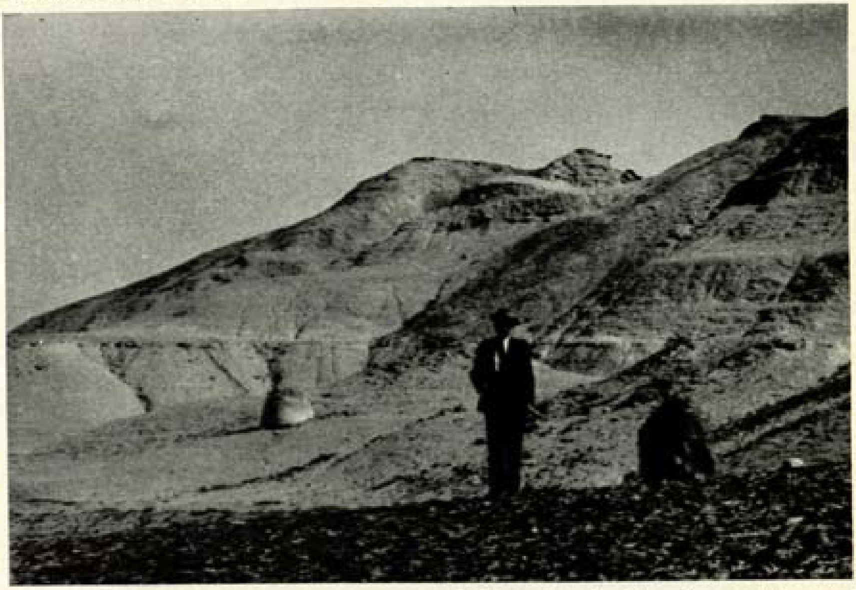
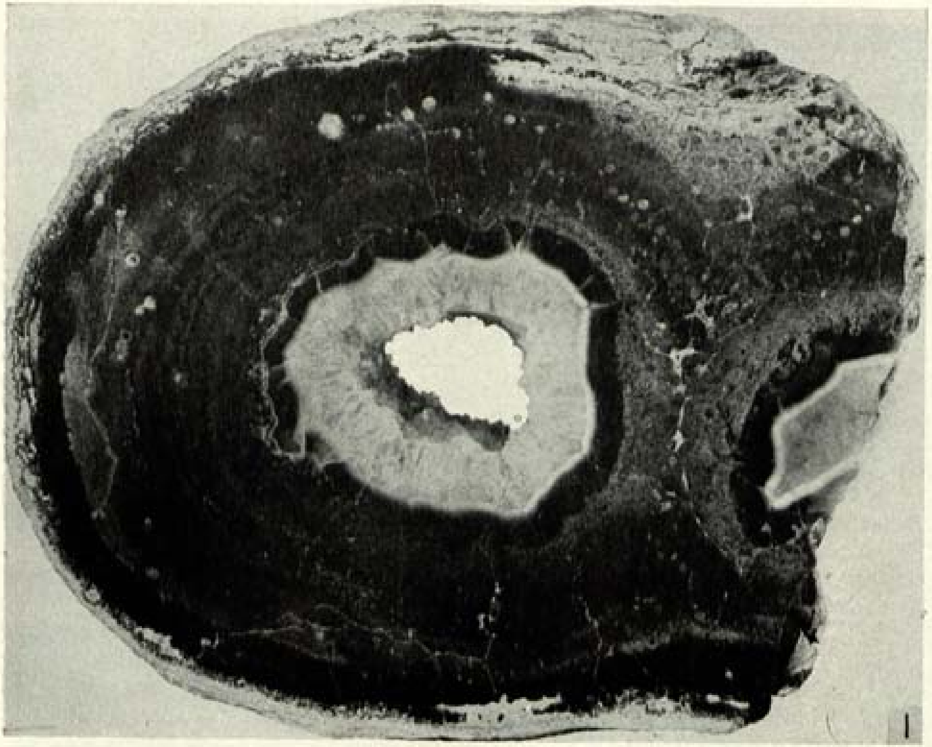


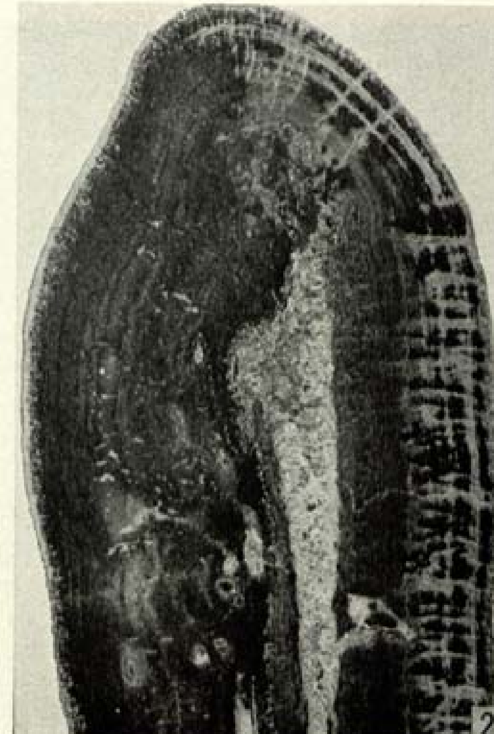
1. Algal pillars in the Bridger formation, Whisky Basin, 27 miles northwest of Green River, Wyo.

2. Group of algal pillars and broken pieces, Whisky Basin.

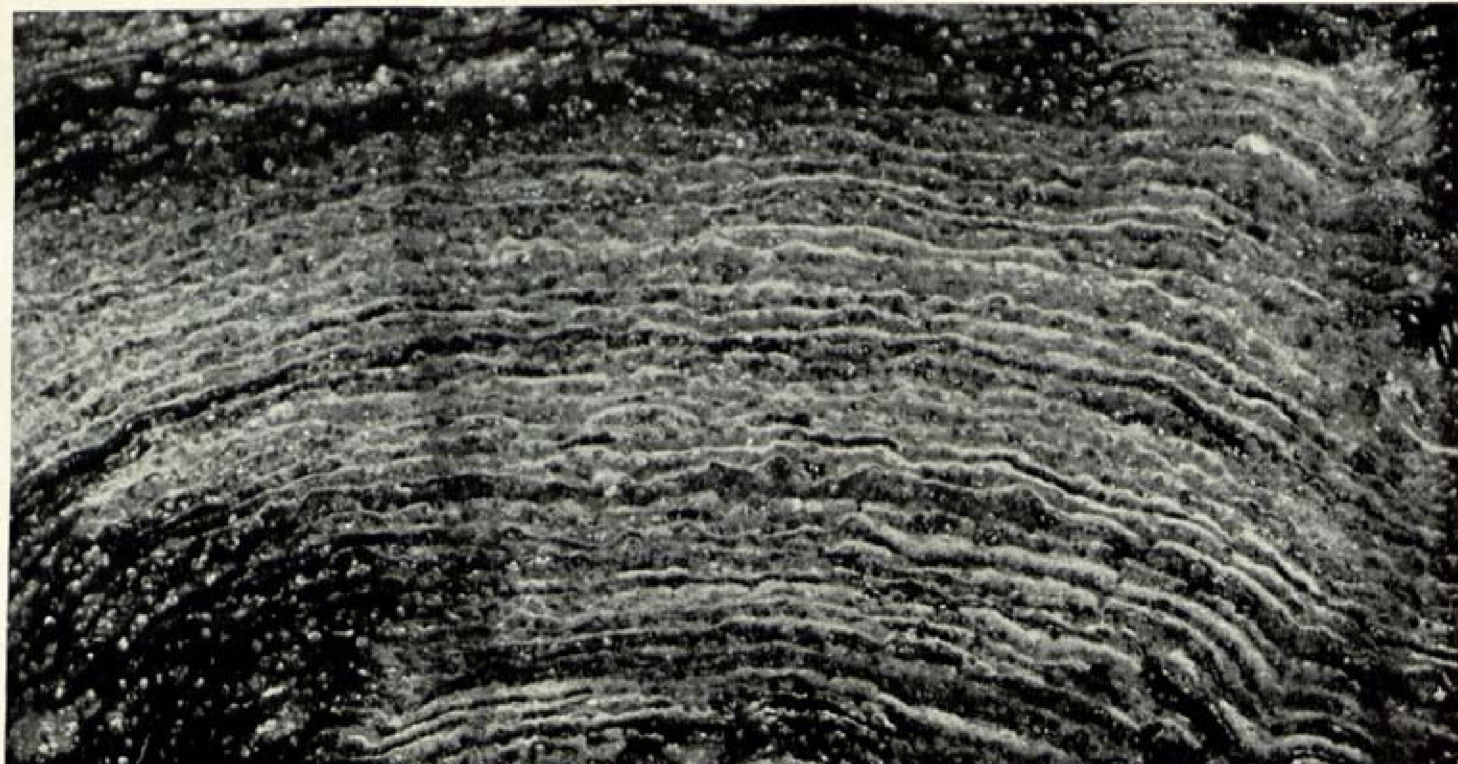
1. Sections of an algal pillar. 2. Broad, open valley of Whisky Basin, with algal pillars in figure 1, from a different angle, in foreground.

3. Lengthwise section through middle of a pillar, showing layers of algal lime covering abandoned insect cases or worm tubes, and arching over the top. Light-colored material in center is calcite that fills the space previously occupied by wood. The larval cases are filled with calcareous sand and ostracodes. Specimen from Bridger formation, 6 to 8 miles southwest of Opal, Wyo. Collected by G. P. Merrill, 1903. × ½.





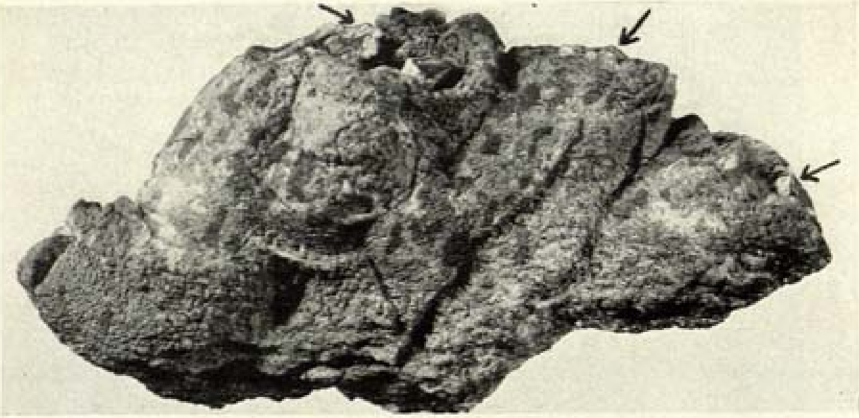
1. Cross section of a "double" pillar built around the fork of a tree. The centers show quartz crystals surrounded by a dark zone of banded chalcedony. Outside the chalcedony is the zone of algal lime showing scattered insect cases and worm tubes. Opal, Wyo. × ½. 2. Lengthwise section of a pillar whose left side collapsed after the original wood had decayed and before calcite filled the empty space. Opal Wyo. × ¾.



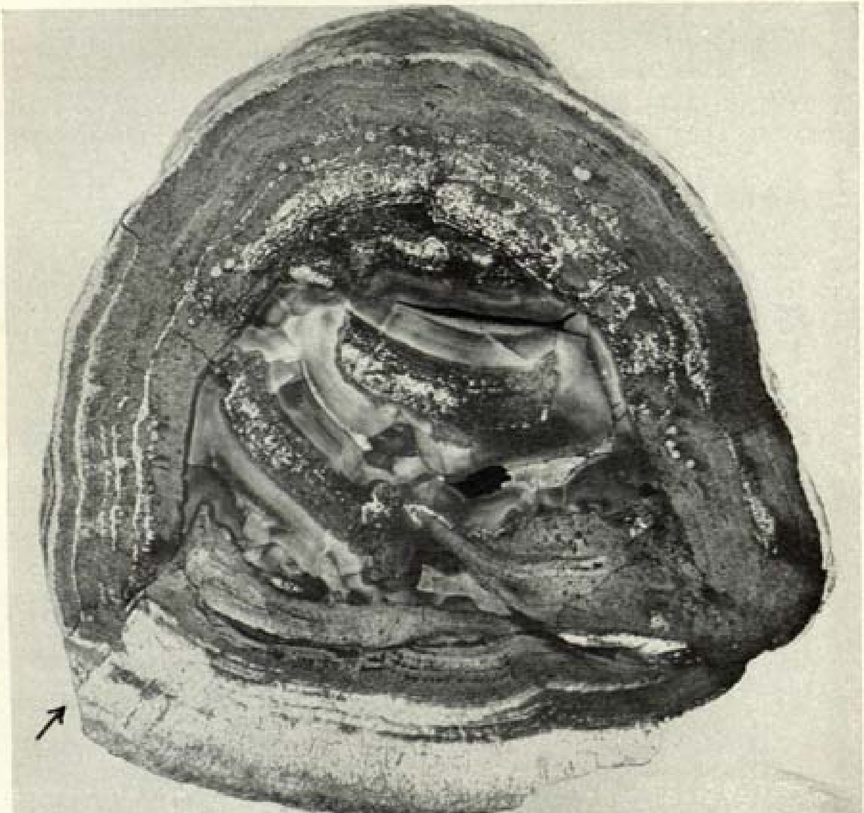
Layers of lime deposited by the activity of algae whose minute, spherical molds can be seen crowded together along the layers. Section from specimen shown in plate 3, figure 2. × 15.

1. Lengthwise section of an algal pillar with silicified coniferous wood at bottom center. Esmeralda formation, 4 miles west of Tonopah, Nev. Natural size.

2. Cross section of a pillar showing banded chalcedony center surrounded by algal lime. The chalcedony occupies the space vacated by wood. Opal, Wyo. × ½.

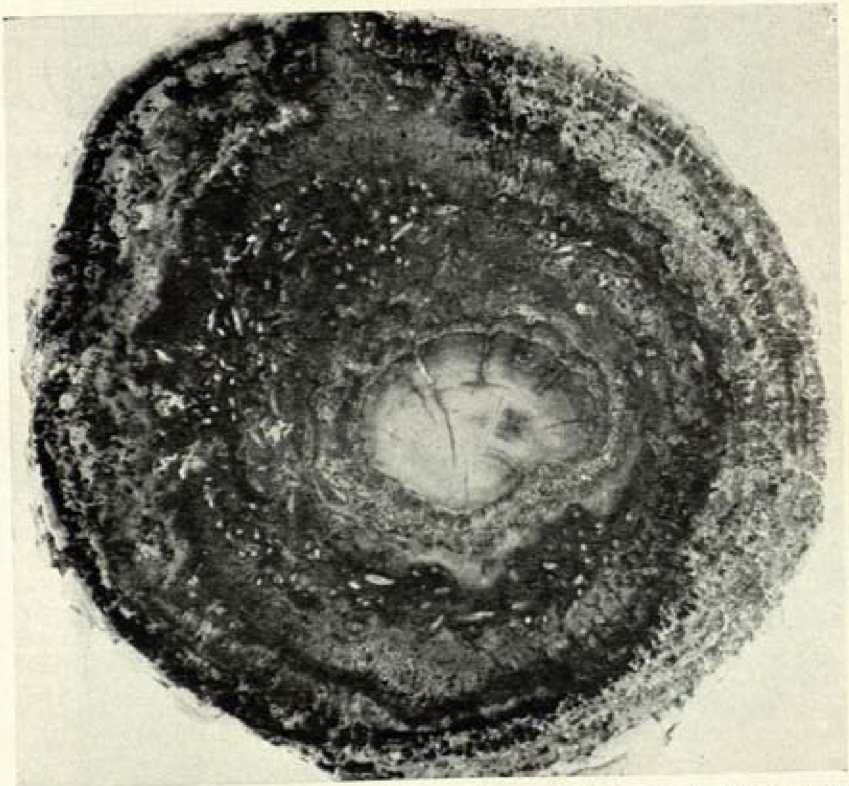


1. An irregular mass from Whisky Basin, showing thick algal lime incrustations around tangled pieces of silicified wood, which was probably drift debris that sank to the bottom of the lake near shore. × ⅓.

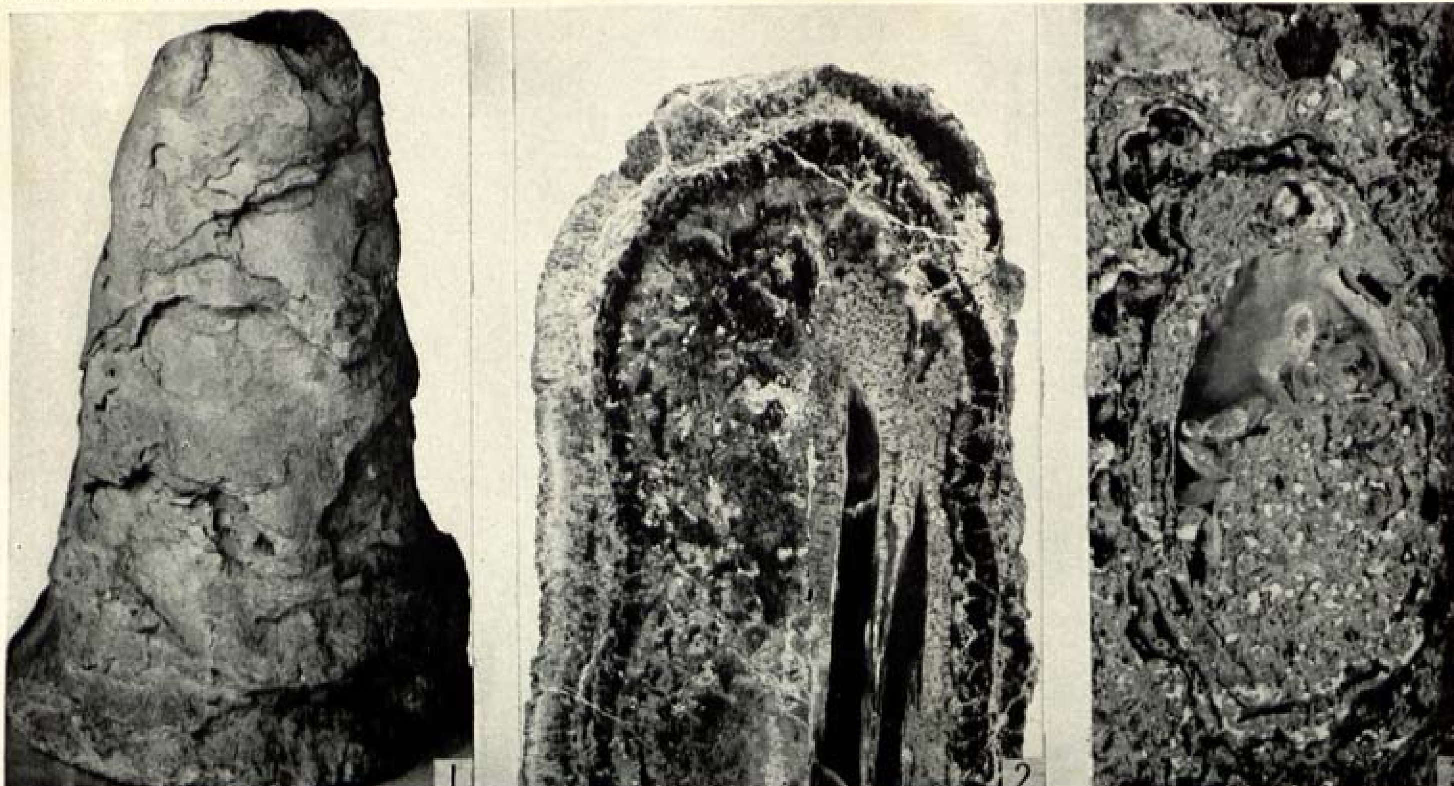


2. Cross section of a pillar that toppled from its vertical position, bashing in the lower side, as shown by break at arrow. Portions of the broken algal cylinder are now in the center surrounded by chalcedony. Opal, Wyo. × ¼.

1. Cross section of a pillar with silicified dicotyledonous wood (dark). From Eden Valley, northeast of Whisky Basin. Natural size.



2. Cross section of a pillar with silicified coniferous wood in center. The minute, spindle-shaped objects are probably larval cases of midges or microcaddis flies. Tonopah, Nev. Natural size.



1. Calcareous geyser cone from Yellowstone National Park. $\times \frac{1}{5}$. 2. Lengthwise section of a pillar showing silicified coniferous wood (dark) to right of center. Tonopah, Nev. $\times \frac{3}{4}$. 3. Cross section of a worm tube filled with calcareous sand below and ostracodes above in the translucent chalcedony. $\times 12$.

Concepts in Conservation of Land, Water, and Wildlife[1]

By Ira N. Gabrielson, *President, Wildlife Management Institute*

[With 3 plates]

Conservation is the wise use of our natural resources. Conservation is not a process of locking up those resources and keeping them for future use as is sometimes charged, but a concept of using wisely, and with care, those resources with which this land was originally endowed. These resources can be divided into two broad groups: the mineral or nonrenewable resources, which can be conserved only by utilizing them wisely and without waste, and the organic or renewable resources which, if properly managed, can continue to produce indefinitely things of value for the human race.

It is with this latter group that conservationists are now chiefly concerned. In the past there have been many conservation programs. There have been abroad groups promoting the conservation of forests, wildlife, soils, and, most recently, waters. There are many smaller groups interested in single phases of wildlife conservation. Each of them has been more or less successful in proportion to the popular appeal and to the strength of the forces behind it. There are still many groups which are primarily interested in individual problems, but there is a growing public understanding of the fact that the conservation of all renewable resources is inextricably intertwined and that it is difficult, if not impossible, to pick out any one element and carry on a conservation program for that alone without affecting, for good or evil, some other important elements.

Americans are proud of the fact that their energy and initiative have developed a great country in record time. There is no similar instance is history of a virgin land being developed into a great agricultural and industrial nation in so short a period of time. While there is much in this record of which the nation may well be proud, our achievements have been accompanied by an appallingly wasteful and destructive utilization of basic resources. Virgin forests were cut, piled, and burned in order to make way for the plow; for years timber was, and still is, too often cut with shocking wastefulness of the present crop and a complete lack of concern for future forest growth. Land that never should have been farmed was broken; vast drainage schemes were promoted at public expense even when such schemes could have nothing but ill effects on the local and national economy.

Into this wastefulness the three elements of ignorance, stupidity, and greed have entered conspicuously. It can be said charitably that in the earlier days much of the waste was due to ignorance. With present-day knowledge of the past waste of the

[1] Reprinted by permission from The Technology Review, vol. 50, No. 3, January 1948, with added illustrations from Outdoor News Bulletin.

national resources, we can attribute a continuation of many of these practices only to stupidity or greed; it is hard to say which is dominant. In spite of the knowledge that is available for the asking, it is still possible for an unscrupulous promoter to enlist businessmen, the chamber of commerce, or other local groups in a dubious drainage or development scheme which lacks many or all of the elements that might make it successful. Despite the record of past mistakes, this Nation is still dissipating and unnecessarily destroying the basic resources on which its future depends.

Land

Someone once said that the future of the human race was entirely dependent on the top 14 inches of soil. Like many epigrams this one contains much truth. All food, most of the clothing, and many other products that fill everyday human needs are products of the soil and water. So far as the future can be discerned, they will always be so produced. The development of the great plastics industry has not changed this picture. While plastics can be substituted for many uses to which metals are now devoted, they cannot replace food and other essentials. In fact, plastics are made largely from products of the soil. Those that have been developed from petroleum products or byproducts were living plants and animals at one time, and those that are produced from cellulose are direct products of the soil.

The fall of many nations has been linked directly to abuse and destruction of that nation's soil. Many rose to greatness on virgin agricultural areas and declined with the destruction of the soil. The same historical sequence is inevitable in this country unless we learn to use more wisely the soils and waters of the United States. Scientists realize this keenly and have been trying for years to impress upon the general public the need for conservation. However, it took the spectacular dust storms of the 1930's, resulting from wind erosion of the arid, drought-stricken plains country, to focus attention, even momentarily, upon some of the basic problems of maintaining our natural resources. Like all farm crops and animals, wildlife, too, is directly dependent upon the soil. In fact, all animal life, including man, is dependent upon plants which are the only living things capable of taking minerals, air, and water, and combining them into the complex substances that are required for human and animal nutrition. When man eats meat, he feeds upon the products of plant development and growth for, as a food, meat is only once removed from plants. Whether fish, fowl, or beast is eaten, man depends ultimately upon vegetation and this fact is one of the primary bases of the conservation concept.

The productive soils with which this country was originally endowed were built by a very complex process that required vast stretches of geologic time. Only by going through an exceedingly time-consuming evolution did soils become fertile and productive. Usually, the first step in the formation of soils is the breaking down and weathering of rock, as the result of wind, water, and temperature acting upon the rocks. Without forming immediately productive soils these rock particles contain mineral elements that provide basic fertility. These broken-down particles of rock may be moved, mixed, shuffled, deposited in layers, torn up and resorted by the action of erosive agents until they become capable of sustaining some type of plant life. A few plants are even capable of growing on the faces of solid rocks and the growth of their roots contributes to the actual breaking down of the rock. More kinds of plants can grow on newly broken-down rocks. As these plants grow and decay, the humus, which they create and return to the soil, enables other and higher types of plants to develop on the same area. Eventually a fertile topsoil is formed

by the incorporation, with the mineral particles, of the decaying remnants of many generations of plants and animals. It is by this process that productive soils are built.

When the white man arrived in North America, he found a continent in which these processes had been going on for geological ages. As a result highly productive soils, naturally some better than others, were found. This natural process permits the return of all materials to the soil and as long as it continues, soils build toward a more productive condition. When the soil-formation process is interrupted, as it is when man develops an agricultural program and begins to take away and market great quantities of the products of the soil, it is inevitable that soil building ceases and soil exploitation is started. Man recognizes this fact every time he fertilizes a piece of land, plows under a green crop, or spreads animal and plant wastes upon the soil.

Soils that are devoted to agricultural crops become more subjected to erosive agents and in the past the result has been that an accelerated erosion of the soils started immediately. Erosion has hastened the reduction of soil fertility far beyond any loss that came from the removal of the elements of fertility from the soil. Fluctuating streams, the choking of stream beds with silt at an extremely rapid rate, and other disastrous consequences follow destructive erosion processes. Soil destruction has been going on in America since the first settlers landed and is still affecting a major part of the land. Net results are easy to see. At the present time, something in excess of 100,000,000 acres of formerly good crop land is now completely unproductive. Some of it will not return to productive capacity for many thousands of years and then only as a result of the slow natural soil-building process. Some of it can be brought back more rapidly by careful handling. Another 100,000,000 acres are seriously damaged and nearly all of the present land used for agriculture has deteriorated appreciably because of our crude methods of exploitation. More than 100,000,000 acres of swamp, marsh, and lake lands have been drained by one device or another. In some cases drainage has produced good agricultural land and in others it has not. In either case, but little thought has been given to a comparison of the value of land in its original condition and its value for agriculture, wildlife, and the preservation of natural resources after drainage.

When the white man came to America, he found a land that was adequately clothed in vegetation, nature's major instrument for retarding erosion. Both the character and density of the vegetation varied with the fertility and character of the land, the amount of rainfall, and the climate. The eastern half of this country was largely an unbroken forested area. In midcontinent the grasslands and prairies were completely clothed with a turf and in the more arid areas of the country desert-inhabiting plants with vast root systems performed the function of soil protection.

To a large extent this vegetative cover has been disrupted, some of it necessarily and some of it needlessly. Under conditions of natural growth the vegetative cover performed other functions in addition to that of inhibiting erosion. It forced water into the soil and held it there stored for the future use of the plants. It maintained ground-water tables and gradually fed the surplus water into the streams. The natural cover of vegetation held to a minimum variation in stream flow, and the stored waters fed permanent streams and maintained ground-water levels with small variation even during long periods of drought. In other words, nature's method for protecting the land, building its fertility and productiveness, and storing water is the natural mechanism by which the soils and vegetative resources can be maintained to the greatest benefit to the human race. A wise national policy

would disrupt this mechanism as little as possible.

Conservationists realize that a return to the natural conditions of centuries ago is neither possible nor desirable. The present population of the country could not be maintained on the low agricultural productivity that existed prior to the voyage of Columbus. Conservationists do believe that the greatest possible use should be made of this natural mechanism of soil preservation. The basis of conservation thinking is that man should work with nature and natural processes rather than in direct opposition to them. This basic concept may be translated into concrete practices by developing permanent vegetation of some sort for all land too steep to farm profitably or having such a soil texture as to be incapable of staying in place under agricultural conditions. In the eastern United States such a program requires the growing of forests, and in more arid sections of the country permanent grass or other ground cover is required. A cessation of drainage programs is desirable until a careful determination has been made of the present value of the land and water and their products, the importance of undrained land in the storage of water, and the effect which draining may be expected to have on the reduction of flash run-off, not only locally but for the entire drainage area involved. Once a complete study is made, a comparison of present values with those that can reasonably result from the proposed drainage should determine whether or not the project is a beneficial one.

On lands devoted to agriculture, we must utilize the best available knowledge to prevent excessive erosion and to maintain soil fertility and productivity. Attainment of the desired goal may often require contour farming, terracing, strip cropping, grassing of run-off strip, construction of farm ponds, and the employment of various other devices by which water is held on and forced into the land to the maximum possible extent. In areas that have been subjected to successive erosion, conservation requires a curative treatment involving gully control, check dams, and permanent vegetation.

Water

Acre for acre, water is often as productive a basic resource as land, and the products of rivers, lakes, and ponds are equally valuable to the human race. The tremendous tonnage of fish, shellfish, and crustaceans used each year for human food and for other uses may be cited as one of the obvious values of areas covered by water. The natural water resources have been abused even worse than those of the land. Fisheries, particularly the inland and coastal bay fisheries, have declined tremendously due to overfishing, the blocking of streams by dams, pollution, or excessive erosion which has silted up the streams and lakes until they can no longer sustain the quantities and varieties of life that formerly thrived in these areas. Sometimes the decline of animal and even plant and human life is due to one of these factors alone but usually it is the result of a combination of two or more man-made troubles. Yet the productive capabilities are there; they have merely been abused.

There has been a slowly growing realization of the necessity for dealing with water control on the basis of an entire drainage basin rather than by isolated projects. It should be obvious that, insofar as possible, water management should start where the raindrop falls. To secure the greatest value from both land and water, agricultural and land management practices should be such as to retain as much rainfall as possible for use on the land. An understanding of this necessity has resulted in the development of a program of soil conservation which, by forcing water into the soil and by storing of water in small ponds, helps maintain ground-water

levels and takes maximum advantage of the combined productivity of the land and water. To the complete surprise of many people it is being demonstrated that water can often produce a value per acre that compares favorably with that obtainable from the best production in farm crops. Slowly we are commencing to realize that there are better ways of utilizing this country's natural resources than to drain water-covered areas solely to provide larger crops which may be already in surplus. A revolutionary change in the philosophy of the average farmer and land manager will be required, however, before the detrimental effects of indiscriminate drainage are recognized; we shall also have to change some of our past engineering practices. Among students of natural-resource problems there is a conviction that a program combining good management of land and water over an entire watershed is the only possible way to stop the dissipation of the basic resources of the country. Obviously to carry out such a program it is unnecessary to advocate valley authorities, or the program of any particular organization or group of engineers. Regardless of which group or groups do the work, there should be no more piecemeal planning and construction of projects for flood control, hydroelectric power, or other purposes.

Conservationists do not believe that it is either good planning or good national economy to flood great areas of good farm land above a dam in order to furnish flood protection to the same or less acreage below the dam. They do not believe that big dams are the solution to this basic problem. They realize that big dams have a place but they believe that the best use that can possibly be made of water is for it to contribute the utmost from the moment it falls on the ground. They believe that these programs should come first; that control at the source will provide greater immediate values than great impoundments far downstream. They believe that proper land and water management will render many flood-control dams unnecessary. They believe that such dams as are a demonstrated necessity will silt up much less rapidly and be of use for a much longer period if the management of water starts at the source.

In other words, groups studying this problem from the over-all standpoint —conservationists, soil experts, biologists—believe that the cart is before the horse when flood control and water management are begun far downstream instead of at water sources. They believe that such programs as have been common in the past are more expensive, less efficient, and less productive for public good than the more logical but less spectacular utilization of water, initially, from the time it first falls on the land. Conservationists believe that land and water management should be combined and started with the raindrop; they most certainly do not believe that the control of water should be delayed until it becomes necessary to deal with great volumes of water which already have become destructive forces.

Another great abuse is the pollution of water resources through the practice of dumping untreated industrial wastes and domestic sewage into the streams and lakes of the country. This abominable practice has been tolerated because it provided a cheap and easy way of solving an immediate problem. Yet the food and recreational values thereby destroyed would often show a loss of public values far outweighing the gains which the offending industry or community may have obtained by its shortsighted and thoughtless procedure. Pollution has played a big part in the decline of the shad fisheries of the Atlantic coast, the oyster fisheries of the Chesapeake Bay, the inland fresh-water fisheries of the Illinois and other rivers. Through dumping sewage and industrial wastes the nation loses each year a staggering sum representing the value of the aquatic

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crops that could be produced in the absence of polluted waters.

Conservationists believe that no individual or group of individuals has the right to destroy publicly owned resources needlessly or for their own immediate profit. Both from an economic and a public health standpoint, it is becoming increasingly important to clean up the polluted waters and thereby to protect human health and restore the biological productivity of part of our natural-resource machinery.

There is one way to accomplish this program. It is necessary, first of all, to stop immediately any new pollution of water; it is then essential to put into effective operation a program for abating the existing sources of pollution.

The Role of Vegetation

Reforestation or revegetation is the first line of defense in both erosion control and water management. Too late has the public realized the mistake in cutting forests recklessly, and the wastefulness of allowing land to pass into an irresponsible ownership in which no thought was given to the future. Still, much progress has been made in the last 40 years in public understanding of the necessity of revegetation, and much public money has been spent in buying back lands suitable for reforestation.

Much of the rough and poor land of the western States is in public ownership and capable of being managed in large blocks with maximum permanent return. The publicly owned lands in the West are valuable chiefly for timber production, watershed protection, and recreational purposes. Some of them have value for grazing, but many of the more arid regions quickly deteriorate when overgrazed, a mistake that is easy to make in an arid land particularly during a drought period. This nation should not make the mistake of allowing highly productive lands to pass into private hands for the purpose of exploitation or destruction, for ultimately they must then be brought back into public ownership for revegetation at great public expense. We should learn by the mistakes of the past. The rough and mountainous lands of the country, the arid grazing lands, and the deserts that are not suitable for agriculture should always remain in public ownership where they can be managed for the protection of all interests and still be made to produce some return.

The basic concept of conservation may be said to be the permanent revegation of all lands not suitable for agricultural development. Such lands in which rainfall is adequate should be restored to forests and when restored, they should be placed under a program of management such as will produce a sustained yield. In that form they will return their greatest value to the nation as well as to the community in which they are located. The more arid lands should be returned to grass or other suitable forms of vegetation.

One of the great mistakes of World War II was the plowing up of vast areas in the Great Plains country which, conservationists hoped, had been permanently placed in grass following the spectacular dust storms of the 1930's. Much public money was spent on the effort to vegetate these lands. Now with high prices and a little better rainfall, it has been profitable to gamble on cropping this land. It is a gamble and droughts will again return to the plains. Will these landowners have either the resources or the understanding to put the land back into grass once prices go so low as to render the gamble unprofitable or when drought begins to cut returns to the same point? Especially when our Government supports a program of high farm prices it is a good guess that they will not and that the public will again be called upon to pay the cost of returning these lands to the only use for which they are basically fitted. The protective vegetation can be utilized for grazing by livestock or wild animals. It can be

utilized permanently only if the vegetative cover is not destroyed by excessive use.

It is hoped that this brief discussion of the role of vegetation has pointed out the importance of plants in the management of lands and waters. Plants are one of the great natural controls since they are highly effective in retarding erosion and regulating run-off. They furnish an indispensable part of the mechanism by which a suitable water table is built and maintained; they build continually toward a more productive soil and they manufacture all the basic foods utilized by all animal life, including man. Can there be any questioning of the belief of conservationists that all land not immediately needed for other purposes should be kept continuously vegetated as a part of any intelligent program of natural resource management?

Wildlife Management

Biologists and naturalists realize keenly that the ultimate fate of wildlife is tied up inextricably with the management of the lands and waters. They realize that a good crop of wildlife cannot be produced on poor and worn-out land any more than a good crop of cattle or corn could be produced on the same land. There is a popular belief that any piece of waste land is adequate for wildlife production. This belief prevails because wildlife, often crowded into such areas, survives in minimum numbers on marginal areas. That does not mean, however, that good crops of wildlife can be produced profitably on such land. For this reason wildlife biologists are keenly interested in maintaining the highest possible productivity of the lands and waters.

There are types of wildlife fitted to live under almost all possible normal variations in vegetative cover and under varying climatic conditions. A reforestation program cannot but help certain types of forest animals. If that reforestation program is wisely carried out, the wildlife values are enhanced. As the timber grows, conditions become better for some forms of wildlife and worse for others. A forest slows down run-off as duff accumulates. Streams which had become intermittent because of forest destruction, often become permanent streams once more as reforestation progresses. Likewise, in areas suffering from excessive erosion any sound program of soil conservation cannot but help wildlife to some extent. If some thought is given to wildlife at the time this program is laid out, this benefit can be multiplied many times.

Many flood-control programs, hydroelectric developments and reclamation projects have been very destructive to fish and wildlife. Often this has been needless since experience shows that some consideration would have provided an opportunity to salvage many fish and wildlife values.

The greatest single benefit of wildlife, although one which it is difficult to evaluate in a monetary sense, is the incentive it affords man for wholesome outdoor recreation. The outdoors still has a major appeal. People go out-of-doors not only to hunt and fish, but to look at and photograph birds, mammals, and scenery. Their methods of enjoying these resources are diverse and that is one of their most wholesome values. There has been a saying circulated for many years that more film is utilized in photographing wildlife than is used on any other subject except babies. A total of 9,854,314 hunting licenses were sold in the United States during 1946 and 11,068,717 fishing licenses were recorded in addition. This is a record amount, but the number of such licenses has grown steadily each year since 1918 when records first began to be kept on a wide scale. Yet these numbers represent only those who are required to obtain a license to hunt or fish; they do not include the great many who can hunt or fish without licenses, nor those who get their fun out of wildlife in other ways.

From an economic standpoint, however, wildlife is also of great value to the country. The fish and other products taken from the streams, lakes, and coastal waters of this country amount to from 4 to 5 billion pounds a year. They furnish a source of wholesome protein food that costs little to produce if the nation gives nature a chance and works with her rather than against her. The only thing the human race is called upon to do to preserve the fisheries is to refrain from destroying the environment on which the fish depend and to regulate their take out of the fish populations so as to leave adequate breeding stock. It seems a small enough investment to guarantee such a quantity of wholesome and nutritious food. A rather hasty survey has shown that the combination of overfishing, drainage, pollution, and siltation of streams and lakes has cut a potential 2 billion pounds a year from possible commercial production.

While engaged in recreation, hunters and fishermen take approximately three-quarters of a billion pounds of meat and fish annually in this country. This harvest could be appreciably increased if intelligent management were applied to the lands and waters.

Fur-producing animals furnish the incentive and the economic return which pioneered much of this land, and the fur taken in the United States under present lack of suitable environment and depleted stocks of fur bearers still aggregates $50,000,000 to $60,000,000 a year. It could be several times that much if this resource had been managed more wisely. There are acres of marshlands, for example, that produce more net return per acre in muskrat fur alone than similar land produces when drained and placed under cultivation.

In addition to these direct values, there is a tremendous business, estimated at 2 billion dollars annually, in furnishing accommodations and providing outdoor clothing and hunting and fishing equipment to those seeking recreation and relaxation in the outdoors. It is one of the major businesses in the country and has a peculiar value in placing much of the money expended for this purpose in the remote and poorer sections of the country. With lands revegetated and properly managed, this business can be increased.

Summary

The basic concepts may be summarized as follows: Conservation involves wise use of renewable resources of the country so as to obtain a perpetual harvest of the production of the lands and waters. Profitable production of American farms and forests can be maintained only by adequate management of the soils to prevent destructive erosion. Water control and land management should go hand in hand and should start from the moment rain falls on the land. There should be a coordinated program over an entire watershed in order to maximize the benefits of conservation. So far as possible, water should be stored in the land where it falls and it should be used to produce crops, to keep the stream flows regular and steady, and to provide ground-water supplies for human and agricultural use. No more land should be drained without careful consideration of its value in the over-all management of water and its total productive capacity before and after drainage. No more pollution should be permitted to start and existing pollution should be cleaned up as rapidly as possible. Once the pollutants have been removed, waters are capable of producing as great a crop of fish as ever. All lands too steep, too light, too sterile to be used profitably for intense agriculture should be revegetated. In the more humid areas lands must be reforested; in the arid sections grass or some of the more arid land plants will have to be restored. The imperative need is to maintain an adequate vegetative cover on all lands not needed for more intensive use. Problem areas, in particular, should

be maintained in grass cover even at the expense of some incidental uses which might be obtained from them. Wildlife is a crop that must be grown the same as any other crop; its production can be integrated with intelligent and better management of lands and water. The recreational value of wildlife is intangible but tremendously important; the monetary and economic value amounts to billions of dollars annually.

The intelligent management of renewable resources is the major problem before America today. While the strikes, divorces, murders, baseball games, and many other features fill the headlines and attract momentary attention, the future of this country depends upon how well its remaining resources are managed, and how effectively the resources can be restored where ignorance, greed, or stupidity have destroyed their productivity.

1. Forests were burned and cut to make way for the plow.
Photograph by U. S. Forest Service.

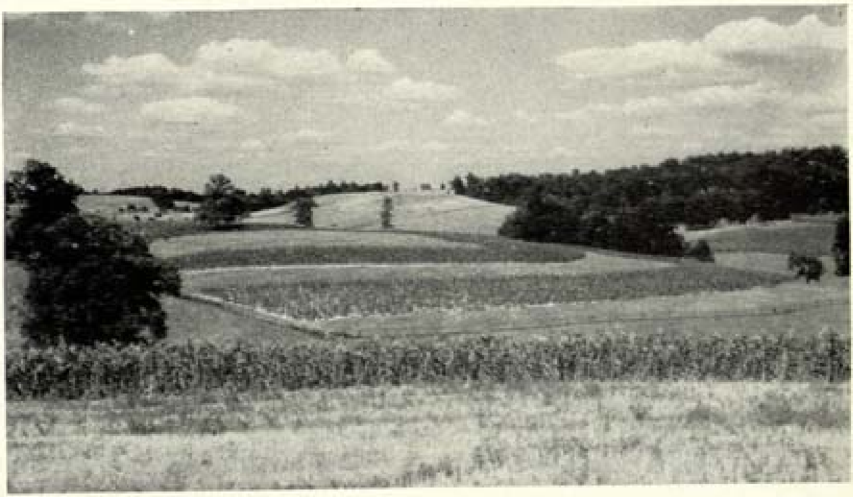
2. The productive soils with which this country was originally endowed were built by a complex process requiring vast stretches of geologic time.
Photograph by Gabriel Moulin.

1. The dust storms of the 1930's focused attention on some of our basic problems.

Photograph by Pathe News, from Underwood and Underwood.

2. Erosion has hastened reduction of soil fertility far more than any other factor.

Photograph by Soil Conservation Service.



1. On lands devoted to agriculture we must utilize our best knowledge to prevent excessive erosion.

Photograph by Soil Conservation Service.

2. Farm ponds have proved their value in the soil conservation program.

Photograph by J. P. Barney.

The Evolution and Function of Genes[1]

By A. H. STURTEVANT, *California Institute of Technology*

Every individual organism is the resultant of the activity of the ultimate hereditary units, or genes, that it carries and of the environmental conditions under which it has developed. The geneticist is likely to lay particular emphasis on the gene as the hereditary component in this dual control, but it must never be forgotten that the environment is also essential. The differences between individuals may be due to differences in either genes or environment. There is one group of characters where caution in interpretation is especially necessary, namely, those having to do with human faculties.

There can, I think, be no doubt that there are differences between people in their inherent, inherited, mental, and psychological potentialities; there can also be little doubt, by analogy with other characters, that there are at least statistical differences between races. But precisely these characters are obviously peculiarly sensitive to environmental effects—to tradition and to social and economic conditions. It seems clear, therefore, that one cannot conclude that there is a very high correlation between the inherited mental potentialities of an individual and the properties that he actually possesses, and this caution is doubly necessary when one compares different races.

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An individual belonging to any of the higher plant or animal groups carries numerous different genes. The exact number cannot be specified, for, while there are several methods of arriving at estimates of the number, none of the methods is very satisfactory. It seems safe to suppose that the number is at least in the thousands, but it may well be in the tens of thousands. Perhaps the next question that a physicist or a chemist might ask about the genes, after their number, would be about their size. It is clear that they are small, but again an exact answer is not possible. They are evidently so small as to be beyond the resolving power of an ordinary miscroscope; they are probably within the size range of large complex organic molecules, but it is not possible to be more specific.

In spite of these uncertainties with respect to such basic matters as their number and their size, genes are important units, for they are responsible for all the characters present in living things, and it is, therefore, desirable to find out all we can about them. One of the many methods that has been used in the study of genes is the comparative one. As a result we now have reasonably satisfactory accounts of the genetic behavior in a wide variety of organisms. Several kinds of vertebrates and of insects are well understood, there is some information on a few other invertebrate animals, extensive data are available on many

[1] From American Scientist, vol. 36, No. 2, 1948 (reprint, Science in Progress, Series VI, 1949), and here reprinted by permission of The Society of the Sigma Xi and the Yale University Press.

higher plants, and in recent years we have come to know a good deal about the genetics of some of the lower plants. Perhaps the most important general conclusion to be drawn from a comparison of heredity in these forms is that, by and large, the same principles apply to all of them. There are differences, but these are not sufficient to obscure the essential similarity.

For some comparative purposes, however, it is desirable to consider a series of rather closely related forms. The best understood group of related species occurs in *Drosophila*—a genus of small flies, 2 to 6 mm. in length, many of which are convenient laboratory objects. The best known is *Drosophila melanogaster*. This is a small yellowish fly with bright red eyes, commonly found about fermenting fruit in most parts of the world. Owing to its short life cycle of about 10 days and to the fact that large numbers of the flies can be reared with little space and expense, *D. melanogaster* has long been a favorite subject for genetical research. More is known about heredity in this species than in any other organism, and much of the modern theory of genetics is based on studies of it.

There are about 500 known species of *Drosophila;* of these about 8 have been reasonably well studied genetically, as many more are less well understood, and there are scattered data on still others (8).[2] The species so far studied do not constitute a random sample of the genus, since several of the more distinct groups of species do not breed easily under usual laboratory conditions; nevertheless the available species do represent considerable diversities of type.

There are a few species hybrids recognized in *Drosophila*, and the study of these has yielded much information; in all cases, however, interfertile species are so closely similar as to be of little interest for present purposes. For the other forms, here under consideration, the method of study has been to investigate each species separately, and then to compare the information on the gene composition of a particular species with that available for the other species. This usually means a comparison with *melanogaster*, since more genes are known in it than in all the other species combined.

The methods used may be illustrated by a few examples. *D. melanogaster*, as stated, is commonly found in most parts of the world. Although there are minor differences between strains in this species, there is, nevertheless, essentially a single "wild type" form to be found everywhere and it is not possible to judge the geographical origin of a specimen or of a strain by an examination of its characteristics. This "wild type" form is the standard of reference for comparison of gene composition. Occasionally one finds, either in laboratory cultures or in wild populations, individuals with definitely distinct characteristics, and such a new feature can often be shown to be due to a change that has occurred in a single gene. Since the resulting new genes are relatively stable, it is possible to establish strains carrying them, and to produce any desired number of individuals showing the distinct new characters.

One such new, or "mutant," gene results in flies possessing shortened, kinky bristles. Specimens with this character agree with the "wild type" in all but one of the thousands of genes they carry; the kinky bristles are the consequence of a single gene substitution. It happens, however, that there are two different genes in the "wild type," a change or mutation in either of which will produce kinky bristles; the two resulting mutant characters are not distinguishable by superficial examination of the flies. Each of these genes in the "wild type" undergoes mutation relatively frequently: it is, therefore, possible to obtain a considerable series of separately arisen strains with such bristles. Crosses be-

[2] Numbers in parentheses indicate references at end of article.

tween flies from these strains show at once that they fall into two, and only two, types. If flies from two *forked* strains are crossed, the offspring are all forked; if flies from two *singed* strains are crossed, the offspring are singed, but if a forked strain is crossed with a singed one the offspring are "wild type." When flies from a series of such types are obtained and examined, a difference does appear; the females are sterile and lay abnormally shaped eggs in many of the singed types, but never in the forked ones.

Similar observations have been made on other species. There are now seven species of *Drosophila* in which two such types are known, and in no species have more than two been found. Furthermore, in several forms one type—evidently singed—has been found to be sometimes associated with female sterility. There can, then, be no serious doubt that in these species the same two "wild type" genes are present and have similar effects on the development of bristles—even though the test of crossing to known *D. melanogaster* types is here not possible.

A frequently occurring mutant change in *D. melanogaster* is that which results in a completely white eye. There are many genes involved in the production of the red eye of the "wild type," but only one is known to cause, when it mutates, a wholly colorless eye. There are other ways of producing white eyes, but these require changes in more than one gene. The same gene of the "wild type" that may mutate to give a wholly white eye is also subject to other changes that give intermediate eye colors: eosin, cherry, buff, apricot, etc. Here again, in no species is there more than one gene known that is capable of changing in such a way as to produce white eyes, and this one is known in 12 species. Furthermore, in several of the other species intermediate stages are also known that are due to changes in this same gene. Therefore it seems safe to conclude, even without the crucial test of crossing to a known *D. melanogaster* white, that we are dealing with changes in the same "wild type" gene.

The principal bristles of the head and thorax are constant in their number, position, relative lengths, and in the directions in which they point in the "wild types" of the various species studied; they are in fact recognizable in a large proportion of all the higher Diptera, including, for example, the common housefly. There are, however, a number of genes in the "wild type" whose mutations affect this bristle pattern. One of the most frequent types of change involves a loss of particular bristles, and there are several different "wild type" genes giving such changes. In general, however, the new patterns resulting from such changes are sufficiently characteristic in *D. melanogaster* so that, with practice, it is usually possible to determine by simple inspection of a mutant specimen which one is concerned. Crosses to known types have consistently confirmed such identifications. The two such types most frequently occurring in *D. melanogaster* are known as *scute* and *hairless;* types closely resembling both of them are known in other species (scute in 10, hairless in 4). Here the high degree of specificity of the patterns is the chief assurance of the identity of the genes.

The examples just given show some of the ways in which homologies may be established between the genes of different species. By such means, and by others similar in nature, rather detailed comparisons have now been made possible between several forms.

Within each species, study of the linkage, or association in heredity, between genes makes it possible to correlate the genes with particular chromosomes, and even to determine in which part of a chromosome each gene lies. It so happens that the chromosome configurations of the various species are not all alike, but they can all be interpreted in terms of six elements, lettered from A to F, which are variously attached to each other (fig. 1). When the genes of

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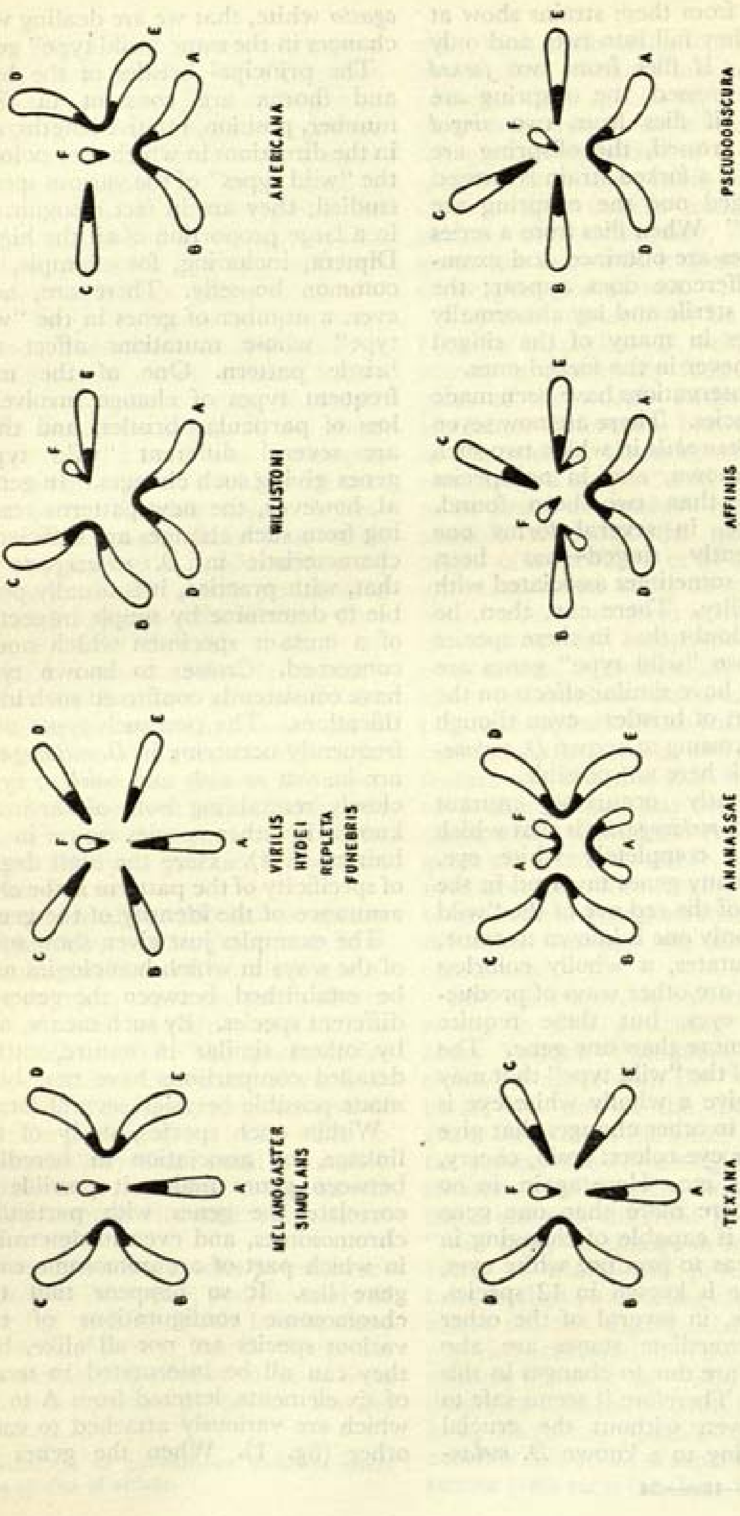

FIGURE 1.—Chromosome elements in *Drosophila*.

each species are located, the striking result is that those that are associated in any one element in one species lie also in the same element in every other species where they can be identified. There is one exception to this rule shown in the diagram—in *D. ananassae* a part of element A is associated with element F—a relation that is known both from direct microscopic examination of the chromosomes and from a comparison of the homologous genes, so that the exception does not in principle upset the parallelism. There are also one or two other probable exceptions, concerning species that are as yet little studied and therefore are not well understood.

This rule of the integrity of the elements serves as a strong confirmation of the identification of the genes; for, if one were making many mistakes in identifying them, no such consistent result would be possible. In this connection it should be pointed out that there are many genes that cannot be utilized in such comparisons, because the characters associated with them are not sufficiently specific. There are, for example, several different pinkish eye colors in most species: these are not distinguishable (with methods now available) within a species without the test of crossing, and they are therefore of little use in interspecific comparisons. Their presence is not contrary to the scheme, but they cannot be used to support it.

Comparisons of this same nature may be made between related species in several other groups, notably among the rodents and in several groups of seed plants. In no case can the comparisons be pushed so far as in the genus *Drosophila*, since there is in these groups no thoroughly understood standard of comparison equivalent to *D. melanogaster*. The data, however, are in agreement with those from *Drosophila* so far as they go; I think there can be no doubt that, in general, related species have essentially the same complements of genes.

It must be recognized, however, that even in the best-known pair of species the total number of common genes indicated by this method lies only between 50 and 60, which is the number common to *D. melanogaster* and *D. pseudoobscura*—the uncertainty arising from the existence of more or less questionable comparisons. This is only a small fraction of the number of different genes present in each species. It can be concluded, I think, that many more are in fact alike. If one considers the bristle patterns of the "wild type" it is clear that the two species are closely similar, and also that there are identical gene substitutions which result in new patterns that are equally similar. This evidently means that the original patterns were alike, because their development was determined in the same way in each species. That is, not only the genes that give similar mutant types are the same, but essentially the whole set of genes controlling bristle development is the same. This argument, when applied consistently to the various characters for which corresponding mutant genes are known, leads to the conclusion that the whole animals are controlled by nearly identical systems of genes.

Such a conclusion may seem to be merely a platitude. After all, these are very similar animals belonging to a single genus, and are much alike in most of their properties. It may be asked—was it worth while to spend so much effort in establishing their essential genetic similarity? Did anyone ever doubt it? The answer is that precisely this point has been seriously doubted, and so it has seemed desirable to examine the situation carefully.

II

The basis for this doubt may perhaps be stated best by first going back a little in the history of genetics. The orthodox view has been that at each particular point, or locus, in each chromosome there is a "wild type"

gene that is consistently present in every such chromosome of every normal "wild type" individual. This locus may at times be occupied by a distinctly different mutant gene, and these constitute the working material of the geneticist, but the resulting individuals are somewhat aberrant and are rather rare. The usual typical individual always carries the "wild type" genes. This is perhaps an oversimplified formulation, but it does, I think, represent something closely approximating the viewpoint of many geneticists.

This view has now been questioned. It is clear that, at least for some loci, there exist several or many nearly equivalent genes, any one of which may be present without any marked effect on the organism (7). The earlier interpretation of a single "wild type" gene at each locus was due to lack of refinement of the methods of the geneticists. It is not yet clear how widespread this phenomenon is; it may be the rule that at each locus there are numerous nearly equivalent genes in the "wild type" individuals, rather than only one typical one.

Some geneticists, impressed by this evidence, have been inclined to go a step farther and to postulate rather frequent changes from one such gene to another. They feel that perhaps the older view of the great stability of genes was also only a first approximation to the true state of affairs; that perhaps the whole system is in a state of flux, and in the course of time the individual genes may undergo extensive changes of function, even to the extent of exchanging their roles in the determination of the properties of the organism.

Perhaps the most extreme statement of this view is that of Harland (4) who writes: "The genes, as a manifestation of which the character develops, must be continually changing" and, ". . . we are able to see how organs such as the eye, which are common to all vertebrate animals, preserve their essential similarity in structure or function, though the genes responsible for the organ must have become wholly altered during the evolutionary process, since there is now no reason to suppose that homologous organs have anything genetically in common."

This is a point of view very different from that to which I have been led by the study of the species of *Drosophila*. It is, however, the opinion of an experienced geneticist, and is based on a large body of experimental data derived from species comparisons within the genus *Gossypium*, to which the cotton plant belongs. That evidence may now be examined.

The wild species of cotton usually have a dark purplish or maroon spot at the base of each petal. Some of the cultivated races lack this spot, but its presence is the rule in the wild forms. In this group, as in many others, species comparisons may be made by crossing distinct forms and studying the genetic behavior of their fertile hybrids. When this is done, it is found that the petal spot has a different genetic basis in some species. The genes responsible for its development in one species may be absent in another one, but the spot is still present and is now determined by different genes. Since it is probable that the ancestors of these two species, back to their ultimate common ancestor, all had the petal spot, it is evident why the conclusion has been drawn that some genes have exchanged functions. The argument becomes even stronger when it is shown, as has been done, that certain other characters of cotton plants likewise show differences between the species in their genetic determination. The facts are, I think, not open to doubt, but there is a special reason why the conclusion seems questionable.

The New World cultivated cottons, from which most of the evidence is derived, have 26 pairs of chromosomes, which may therefore be conveniently represented by the letters of the alphabet (fig. 2). It is clear from several

kinds of evidence that these plants are ultimately of hybrid origin, the two parents belonging, respectively, to the group of Old World cultivated types (the only forms known in the Old World before the discovery of America), and the New World wild forms (of no economic importance).[3] Each of the two parental forms has 13 pairs of chromosomes; in the artificially produced hybrid the maternal and paternal chromosomes fail to pair, and the plant is sterile. Accidental doubling of this complement of 26 chromosomes has given rise to the fertile New World cultivated types.

The two parental types may be supposed to be related in the same way as are the different species of *Drosophila;* in any case each of them has the full set of genes necessary to produce a cotton plant. When first produced, therefore, the form with 26 pairs of chromosomes had these genes present twice. In general in such a hybrid one of the duplicating pairs of genes is enough to produce a given character, and the other is likely to be lost by accident. What has happened, then, appears to be that one set of genes necessary for the petal spot has been lost in some of the New World cultivated types, whereas in others this set has been retained, but the corresponding set from the other original parent has been lost. On this basis, then, it may be supposed that the differences in genetic determination are only apparent—the genes concerned are really the same, and are descended from

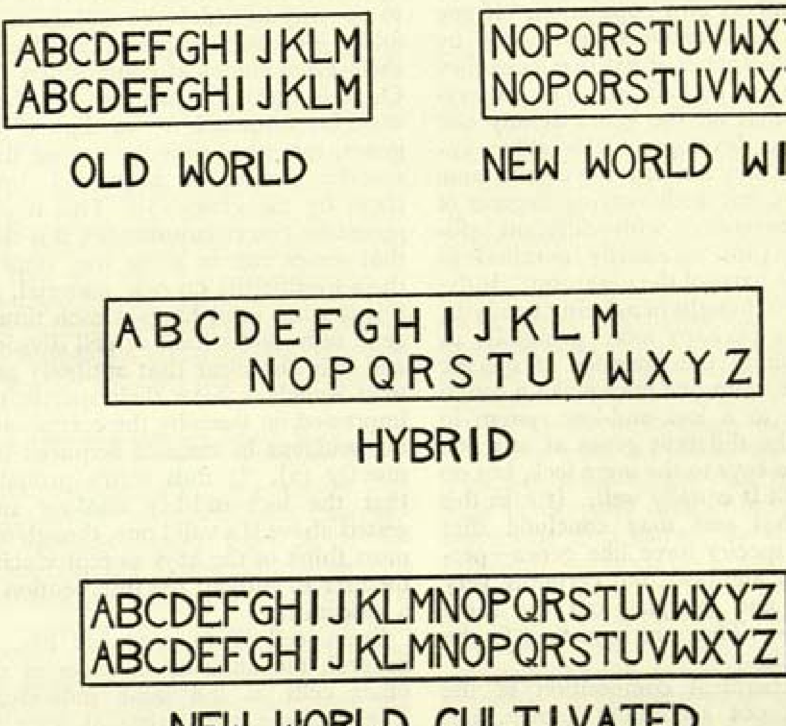

FIGURE 2.—Chromosome constitution in the cotton plant.

[3] It is not clear where or when these forms crossed to produce the New World cultivated types. These questions are of great interest, but cannot be discussed adequately here.

identical genes in the common ancestor of the two 13-chromosome types.[4]

III

There may seem to be a contradiction in what has been stated. I have argued that related species have essentially the same sets of genes, and yet I have admitted that within one species there may be a series of different but similar genes at any one locus in different members of a population. If one studies the characters conditioned by the various genes at any one locus they turn out to be related. The impression is that all the genes at any one locus are developmentally alike; apparently they are carrying on the same function, but with varying degrees of efficiency—often with different efficiencies (not necessarily parallel) in different parts of the organism. If the genes are thought of as being catalysts, or, as is perhaps more probable, as conditioning the presence of specific catalysts, then one may make a rough analogy to a lock-and-key system in which the different genes at any one locus are keys to the same lock, but do not all fit it equally well. It is in this sense that one may conclude that related species have like genes—perhaps not identical, but certainly very similar, and carrying out the same functions. They are keys that fit the same lock.

The chemical composition of the genes is not accurately known, but evidence is accumulating that seems to make it most probable that they are largely or entirely nucleoprotein in nature. The indication of a protein component is of considerable interest, for it suggests that the problem of gene specificity—that is, how it happens that each gene has properties different from those of its fellows—is an aspect of the problem of protein specificity. This in turn means that the geneticist may expect help from the techniques and results of other biologists who are concerned with protein specificities—such groups as enzyme chemists and immunologists.

There is a current tendency to look upon protein specificities as being due to the way in which the molecules are folded—to their shapes rather than to their gross chemical composition (6). On this basis the primary specificity may be supposed to be that of the genes, the other proteins having their specific properties impressed upon them by the genes (3). This is suggested by two circumstances; it is clear that genes can in some way impress their specificities on new material, for this is what must happen each time a gene reproduces itself at cell division, and it is also clear that antibody proteins somehow have their specificities impressed on them by the corresponding antigens in cases of acquired immunity (5). It thus seems probable that the lock-and-key analogy suggested above is a valid one, though one must think of the keys as reproducing themselves without the intervention of a locksmith.

Every cell of an organism has, in general, the same set of genes as the other cells in the same individual. The problem that arises at once is: how is differentiation possible? If the characters of an organism are dependent on its genes, it follows that the different properties of the various parts of one organism are under gene control, yet the same genes are present in all these parts. This may mean, in terms of the lock-and-key interpretation, that in any given part of the organism all the keys are present but only some of the locks; in other words, that the outcome is determined by which substrates are present rather than which gene-controlled enzymes. This is, however, probably an incom-

[4] This account is somewhat simplified. In particular, some of the evidence is derived from comparisons between different 13-chromosome types. There is, however, a possibility that these are themselves derived from doubling of the chromosomes of still earlier hybrids between forms with lower numbers. So long as this possibility exists these species cannot furnish conclusive evidence for a change in function of genes.

plete picture, since it may also be possible that both substrate and enzyme are present, but some other condition (e. g., the hydrogen ion concentration) prevents their interaction.

The relation between different forms of the same gene may be interpreted along similar lines. The effects of these different forms are often not parallel in different parts of the same individual. There is, for example, a gene in the "wild type" *Drosophila* that mutates to produce a type called yellow. There are several different mutant forms of this gene: yellow–1 results in yellow bristles and yellow wings; yellow–2 causes yellow wings, with little effect on the bristles; yellow–3 produces yellow bristles and dark wings. In such cases as this—and they are very frequent—it may be supposed that there are related but slightly different substrates in different parts of the body, and therefore the efficiencies of the slightly differently shaped enzymes are not necessarily parallel.

If one accepts the view that there are fairly numerous slightly different genes at many loci, it is probable that those which are concerned in particular reaction systems need to be adjusted to each other. If one gene is working at a high level of efficiency, it is probable that the other genes that influence related reactions should also be working at high levels in order to produce a harmonious and properly adjusted system, though it might be possible to have an equally successful organism if all the genes concerned were working at a lower level. There is some evidence that precisely such differences do occur between related species. It may be suggested that gene systems gradually drift apart in their levels of activity during the differentiation of species; in that case much of the sterility and inviability often found in species hybrids and their offspring may be due to bringing together genes that differ in their levels of activity rather than in their specific effects on development.

The view that related forms of organisms owe their resemblances to the possession of common genes leads to an interpretation of homology. This is a biological concept that lends itself rather easily to somewhat mystical speculations. Accordingly it has not often been seriously discussed in connection with the results of modern experimental work. There is, nevertheless, something real in the relations covered by the term, whether one considers serial homology within an individual or the homologies between organs in different groups of organisms. The point of view here developed leads to the interpretation that two organs are homologous to the extent that their development is conditioned by the same genes. One consequence of such a formulation is that homology becomes a relative, rather than an all-or-none, phenomenon. This result seems to me an advantage, since it suggests the possibility of a quantitative mathematical approach.

If genes do not change their functions, but only change in the relative efficiency with which they carry on their predestined ones, it follows that organisms also cannot develop new functions—which is obviously contrary to fact, for there can be no doubt that new functions do develop in the course of time. It may be taken as probable that most of the genes present in an organism are performing functions that are advantageous to the organism, for otherwise they will not long persist. This is not a teleological view, but one that follows from the observation that most changes in genes are in the direction of loss of activity. Evidently the only stable condition of the gene composition of a particular locus is the absence of the gene in question, and unless there is selection for some particular function resulting from the activity of the genes at that locus, there will come to be no gene there. Most of the genes, then, are needed by the organism, and cannot well be spared for the production of new func-

tions, even when they happen to change in such a way as to initiate new reactions. It seems likely that the most favorable condition for the production of such new functions is one in which some of the usual genes are present in duplicate. Cases of hybrids with doubled chromosome numbers, such as the cottons discussed above, furnish such an opportunity, for in these cases there is a whole extra set of genes, whereas a single set is all that is needed to carry on the functions normal to such an organism. There is evidence, particularly in the case of the tobacco plant (2), that such hybrids gradually lose one set of genes—or rather parts of the set derived from one original parent, and other parts of the set derived from the other parent. Nevertheless, a considerable period is present in which duplicate genes are present and are available for the trying out of new experiments without the loss of any of the established and useful reactions.

This cannot be the only answer to the problem, for hybrids of this kind, while rather frequent in the higher plants, are very rare in animals, and animals also develop new functions in the course of evolution. It may be suggested that here also there is a source of new genes. It happens that in certain of the Diptera, including *Drosophila*, the chromosomes in the salivary gland cells are unusually large, and permit a study of the details of their structure to a degree of refinement nowhere else attainable. One result of such a study is the discovery of "repeats"—small sections present in duplicate (1). It is not known how widespread the "repeats" are, for they cannot be detected in most material. Little is known as yet about the gene content of such "repeats." However, it seems probable that they occur in most chromosomes, and that they do in fact represent duplications of genes. These "repeats" may, therefore, be a source of extra genes that are not needed for the maintenance of existing functions, and that may therefore be used by the organism in trying out new kinds of reactions.

One thing that is definitely known about genes is that they reproduce themselves. At least once per cell division, on the average, each gene somehow conditions the formation of a copy of itself. On the view that gene specificity is due to shape rather than to gross chemical composition, the simplest assumption is that the new gene is moulded about the old one. This process may be pictured most easily if each gene is thought of as being only one layer thick, so that determination of the shape of one face automatically fixes the shape of the opposite one also.

There are in *Drosophila* some dozens of successive cell divisions between the egg of one generation and that of the next. It is not known how many generations of individuals separate the members of one species from those of another species, but hundreds of thousands is clearly a conservative estimate. Multiplying these two numbers together, we find that like genes in distinct species must have resulted from some millions of successive copyings during the long period since they had a common model. Whatever be the process of gene reproduction, it is evidently an extraordinarily precise one.

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The Sense Organs of Birds [1]

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[With 4 Plates]

Introduction

Part of the interest and sympathy of man for birds undoubtedly arises from the sharing of similar worlds of sensory experience. Both birds and anthropoids, almost alone among animals, are excluded for practical purposes from the world of smell. "They haven't got no noses, the fallen sons of Eve," sang Quoodle. And he might have said the same of the descendants of *Archaeornis*. Birds and anthropoids are also almost alone in having both excellent sight by day and excellent hearing. Consequently it is easier, in some respects, for man to enter imaginatively into the life of a thrush than into the life of a dog, even though the latter is a closer cousin and the relationship has been enhanced by centuries of domesticity.

This point is made at the outset because in what follows it will generally be convenient to take the performance and structure of human sense organs as the yardstick of comparison. Each of us has a direct awareness of the excellence of his own sense organs and of the ways in which they can cheat him. So it is more informative to say that the eye of a buzzard equips him to recognize a mouse three times as far off as a man could hope to than to say that his visual acuity is 5. Such comparisons, however, emphasize differences rather than similarities, and they ought not to be allowed to obscure the over-all resemblance in the perceptual worlds of man and birds.

It is true that much of the sensory equipment of all vertebrates is essentially similar. The senses of warmth and cold, of pressure and tension, of linear and angular acceleration, of taste, and of pain are all concerned in a greater or less degree with the complicated process of self-regulation necessary to maintain the organism as a going concern. The maintenance of body temperature and of posture, the regulation of the heart and other viscera, the rejection of inappropriate food and the avoidance of immediate injury are aspects of this process in which the part played by sense organs is fairly evident. And, so far as the task is broadly the same in all warm-blooded animals, it is scarcely surprising that the sensory equipment concerned with it conforms rather closely to a common type.

Against this background the "distance receptors," the organs of vision, of hearing, and of smelling, are conspicuous for the changes which have occurred in them in the evolutionary history of the vertebrates. The vestibular (nonauditory) part of the ear, which is concerned exclusively with the appreciation of position and movement of the animal in space,[2] is virtually identical in structure in all

[1] Reprinted by permission, with slight revision by the author, from The Ibis (the journal of the British Ornithological Union), vol. 90, April 1948.

[2] It has been suggested by Ising that the vestibule of birds has an additional special function (see p. 326).

vertebrates, whereas it is difficult to recognize any similarity at all between the auditory parts of the ears of a fish and of a mammal. And though the eyes of vertebrates necessarily have the common structural plan to which they were committed at the dawn of their history, there is great variation in detail even in quite closely related animals; and such attributes as color vision and the power of accommodation have been repeatedly lost and reacquired.

It is not surprising that this should be so, for, given the ground plan of vertebrate organization, it is the performance of the distance receptors, more than any other single factor, which limits the field of an animal's activities; and the evolution of new habits must go hand in hand with appropriate changes in the balance of that performance.

The distance receptors of sight and hearing (we still know almost nothing of smell) are very far from being simply physical devices whose function is "to tell the brain what is there." Physical laws set an absolute limit to what they can do, but unless great care is taken in applying the laws in a biologically relevant way, it is found that their performance in some respects betters what a physicist would admit to be possible, while in others it fails mysteriously to achieve what he would consider easy and desirable. The reason is fairly evident to the biologist. The organs of sight and hearing are vulnerable, bulky, and expensive to maintain, and natural selection ensures that their performance is pushed to the limit in those respects only which have survival value in the circumstances of the animal's life; while refinements which are not so necessary, if they interfere with the primary requirements, or even if they only represent a significant overhead charge on the animal's energy balance sheet, are dropped like a hot brick. Moreover the eye and, to a less extent, the ear are integrative centers. They do more than decode a pattern of physical stimuli into terms of nervous impulses. In some respects they stand in the same relation to the higher integrative centers in the brain as do subeditors to the editor of a newspaper. "Information received" is marshalled and the pursuit of further information is organized without reference to the editor's office, which gets only carefully selected and documented items. The greater part of the incoming news is filed or blue-penciled before it has a chance of affecting the policy of the paper as a whole. The distance receptors are, therefore, far from being the "passive linear systems" of a physicist's dream.

It is easier to interpret the structure and function of the distance receptors and to understand some of their limitations if they are looked at historically for, though they are rebuilt in each generation, they are not redesigned. The basic specification, hundreds of millions of years old, is smothered with emendations, additions, and deletions, but it is still there; and all the changes have represented workable modifications within the framework of the original design. The unborn baby (and the unhatched bird) has the task of fashioning for each ear a frequency analyzer of great sensitivity, resolving power, and range from a design, inherited from its fishlike ancestors, which is basically the design for a seismograph. Trivial modifications may have occurred in any or every generation, but there must always have been continuity, and never an opportunity to scrap and start again. The finished job is naturally very different from a physicist's conception of what it ought to be. But for the biologist it is a delight to find what perfection is achieved with the means available and how subtly the most unlikely means are used—how, for example, the ear of the mammal has taken over a few superfluous bones and muscles from the reptilian jaw and used them to make what an engineer would recognize as an im-

pedance-matching transformer incorporating automatic volume control.

The organs of sight

The eyes of birds are progressively conservative. They represent the culmination of a process of development which is traceable back to the earliest land-living animals, and which has been continuously in one direction, toward the perfection of daylight vision. Human eyes are the product of two revolutions, for man's earliest mammalian ancestors, unlike their reptilian forebears, were small and nocturnal, and only recently, by geological standards, has his family come out again into the daylight. In the nocturnal epoch large eyes no longer had the same survival value, since resolving power had to be sacrificed to sensitivity, which is nearly independent of the size of the eye; and man's family emerged from it with eyes loose in their orbits and small in proportion to the skull, but forward-looking and very mobile (fig. 1).

There has been no nocturnal epoch in the evolution of the birds, and evolutionary pressure has been consistently toward large eyes. The skull is built round the orbits, which fill the width of it completely, and the eyeballs fit the orbits so tightly that their freedom of movement is slight or (as in the owls) nil. Most of the important differences between human and avian vision are traceable to this history, while most of the similarities reflect the similar requirements of the present day.

Leaving aside for the moment the advantages of mobility and binocularity, the bird's eye, considered simply as a camera, is the better instrument. It can be seen from figure 2 that there is less optically wasted space, and that the aperture (the ratio of maximum pupil diameter to focal length) is greater. Moreover the retina is shaped so as to lie almost wholly in the image plane, so that all distant objects within the visual angle are sharply focused on the photosensitive cells, whereas in the human eye this is only true of objects lying close to the optic axis.

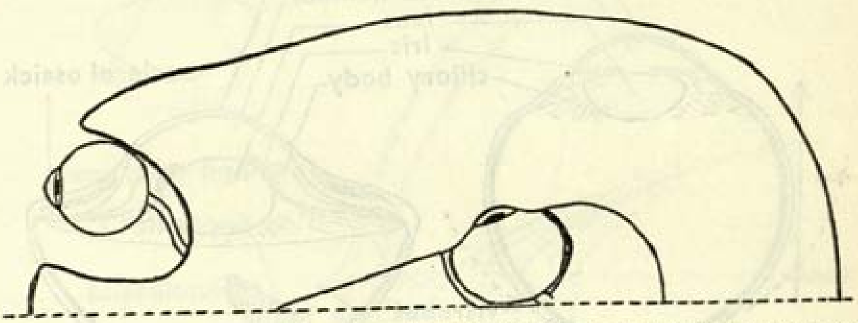

FIGURE 1.—Schematic horizontal sections of right half of the heads of man and sparrow to show the proportions of eyeball and orbit. Scale chosen to make the eyeballs of equal depth.

In birds, moreover, the iris and the accommodatory mechanism—the stop and focusing adjustment—are actuated by striated "voluntary" muscles. The operation of accommodation is shown diagrammatically in figure 3, *a*. The action of Crampton's muscle is to pull the margin of the cornea inward, causing a compensatory outward bulge of the center. Brücke's muscle drags the ciliary body toward the axis of the eye, and this in turn squeezes the lens, increasing the curvature, especially of its external surface.

Man's ancestors lost this mechanism when they became nocturnal, and the human eye has only an unsatisfactory makeshift which becomes more and more inefficient throughout life. Both the muscles of accommodation and the muscles of the iris are unstriated and, compared with those of the bird, sluggish in action.

The maximum accommodation of a 20-year-old man is about 10 diopters (i. e., equivalent to inserting a spectacle lens of 1/10-meter focal length in front of the eye). For the majority of birds accommodation has a range of at least 20 diopters. For the cormorant it is said to be 40–50 with the lens alone. Diving birds have to cope with the special difficulty that under water the outer surface of the cornea no longer contributes appreciably to the total refraction of the lens system; so that, in addition to accommodation for close range, the lens has to contribute an additional 20 diopters or more to compensate for the loss of the cornea when the eye is immersed. As might be expected, Crampton's muscle is degenerate in diving birds, while Brücke's muscle is proportionately enlarged and the deformation of the lens in accommodation is enormous (fig. 3, *b*). In the cormorants the iris is very muscular and the sphincter iridis muscle assists in compressing the anterior part of the lens.

The retina consists of four well-defined layers of cells, the outermost of which is the opaque, black, and nonreflecting chorioid layer.[3] Immediately within this lies the layer of photoreceptive elements, the rods and cones. Then comes the layer of bipolar cells and, finally, the layer of ganglion cells, each of which is extended into a nerve fiber which runs in the optic nerve to the brain (pl. 1).

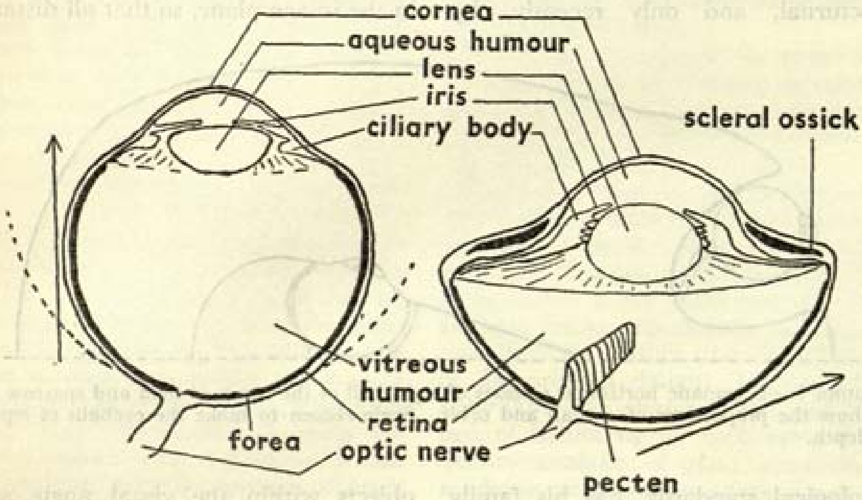

FIGURE 2.—Lower halves of the right eye of man and left eye of swan. Position of image plane of human eye dotted. The arrows point forward.

The names "rod" and "cone" are descriptive of the shape of these cells in the human retina and are not very appropriate for birds, whose cones are much thinner and more rodlike than are human cones. There are, however, important anatomical and physi-

[3] The outermost pigment-cell layer of the retina is distinct in its development from the innermost pigmented layer of the fibrous wall of the eyeball which is the chorioid, s. str., but structurally and functionally the pigment-cell layer belongs to the chorioid rather than the retina in birds and mammals, and it is convenient to use the term chorioid to include the pigment-cell layer.

ological differences between rods and cones which seem to be consistent in all vertebrates. Each cone typically connects with its own group of bipolar cells and each such group with its own ganglion cell. It is rare, therefore, to find that an optic nerve fiber represents more than four or five cones, and in the *area* and *fovea* (see below) there is strict one-to-one correspondence. On the other hand there are always many rods connected with a rod bi-

suited for the registration of detail in a brightly illuminated visual field. The rod system, because of its extensive summation, is comparatively incapable of resolving detail but can register an achromatic picture of the gross features of the field at illuminations so low that the cone system is quite blind. We may expect, therefore, to find, as in fact we do, that cones are predominant in the retinae of eyes which are exclusively diurnal

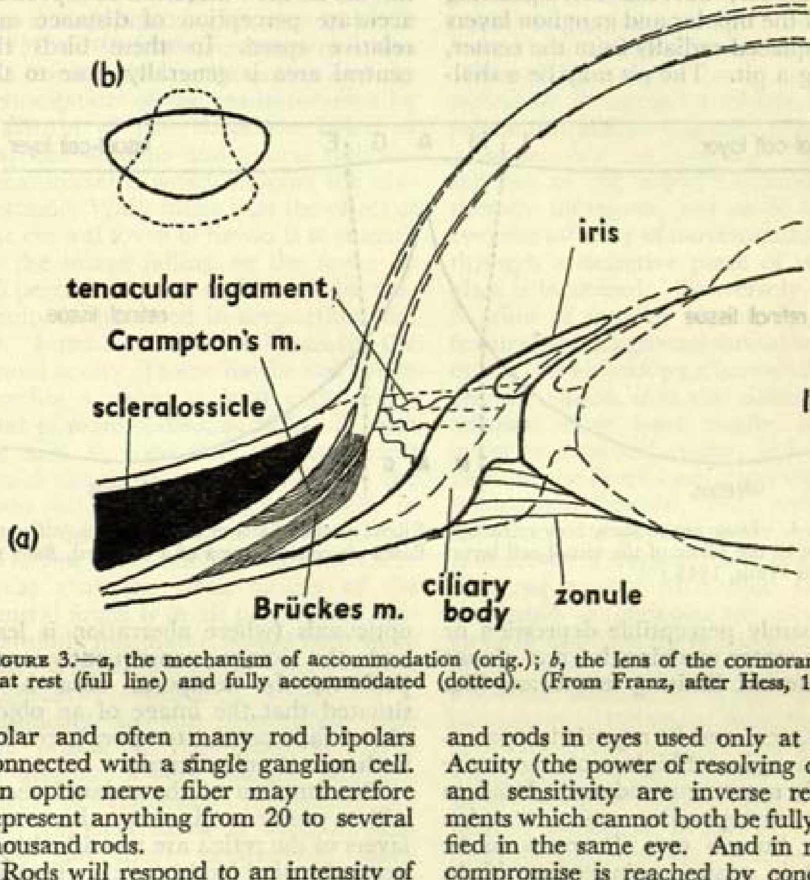

FIGURE 3.—*a*, the mechanism of accommodation (orig.); *b*, the lens of the cormorant's eye at rest (full line) and fully accommodated (dotted). (From Franz, after Hess, 1910.)

polar and often many rod bipolars connected with a single ganglion cell. An optic nerve fiber may therefore represent anything from 20 to several thousand rods.

Rods will respond to an intensity of illumination from 1 to 10 thousand times less than is needed to excite the cones. But within their more restricted range the cones are responsive to much smaller percentage changes in intensity; and it is the cones which are responsible for color vision.

The cone system is consequently and rods in eyes used only at night. Acuity (the power of resolving detail) and sensitivity are inverse requirements which cannot both be fully satisfied in the same eye. And in man a compromise is reached by cone predominance near the axis of the eye where the image is coincident with the retina and rod predominance toward the periphery.

The retina of a diurnal bird's eye is cone-rich everywhere, but there is frequently a good deal of local differentiation. There may be one or two

areae and one or more foveae. An area is a part of the retina in which rods are generally few or absent and cones are particularly tightly packed and individually represented by optic nerve fibers. Because of the corresponding increase in the number of nerve cells, the inner layers of the retina are thicker, so that a perceptible ridge or hummock is visible to ophthalmoscopic inspection. A fovea is a part of an area in which the density of cones is even higher, but the corresponding cells of the bipolar and ganglion layers are displaced radially from the center, leaving a pit. The pit may be a shal-

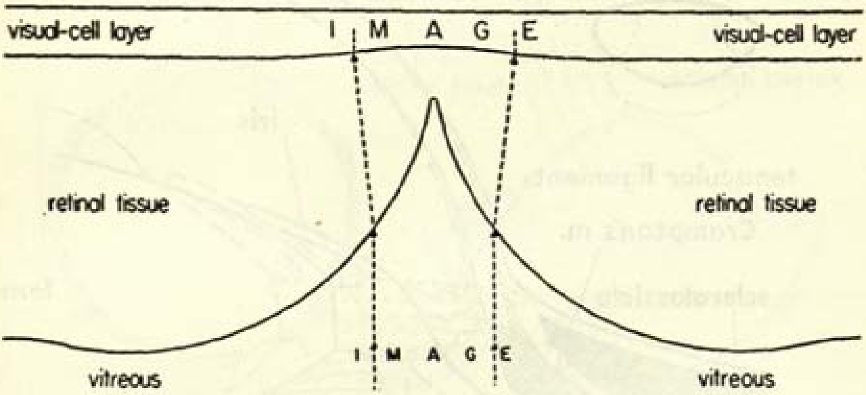

FIGURE 4.—Diagram to show how refraction of light at the clivus of the fovea magnifies the image in the plane of the visual cell layer. Based on central fovea of a buzzard, *Buteo* sp. (From Walls, 1943.)

low, barely perceptible depression or a deep crater reaching down to almost the external limiting membrane (fig. 5).

The area must be regarded as potentially a region of high resolving power both for movement and static detail, as is the corresponding macular region of the human eye. It seems to be absent in many grain-feeding birds. When present it usually conforms to one or other of two distinct lines of specialization. In one line the area tends to extend like a ribbon round the retina in a horizontal plane. In the other, the tendency is toward the formation of distinct central and temporal areae (pl. 2).

It is tempting to correlate the first line of specialization with habits which give a special importance to the horizon, and, in fact, the birds illustrated are those of the wide open spaces—prairie, moor, sea, and lake—while there is no evidence that a ribbonlike area is ever found in the eyes of forest dwellers. The second type is characteristic of birds which, because they pursue fast-moving prey or, like the hummingbirds, feed from flowers on the wing, need an especially accurate perception of distance and relative speed. In these birds the central area is generally close to the optic axis (where aberration is least and the image consequently most perfect); the temporal area is so situated that the image of an object ahead falls on the temporal areae of both eyes simultaneously.

The function of the avian fovea is still a problem. In man the neural layers of the retina are nourished by a network of blood vessels, through which light has to penetrate to reach the photosensitive layer. The radial displacement of the bipolar and ganglion layers from the fovea permits light to reach the cones of this area unobstructed by a filter of blood capillaries. Since the resolving power of foveal vision is very close to the

theoretical maximum, the absence of obstruction is in itself worth while, and is possibly a sufficient reason for the geometrical arrangement which is found. In birds the situation is different. There are no retinal blood vessels and no apparent advantage to be gained by displacing cells of the neural layers whose transparency in life is very nearly equal to that of the vitreous humour. The extreme regularity of the bird fovea (in contrast to the primate) suggests that the shape is of functional importance. We owe to Walls (1937, 1940) both the suggestion that the fovea has a lenslike action and the resuscitation of the measurements by Valentin of the refractive index of vitreous humour and neural retina—measurements which support the suggestion. Walls infers that the effect of the central fovea of hawks is to magnify the image falling on the fovea by 30 percent in area, and concludes that acuity is increased in proportion (fig. 4). Later he states that, "*foveally*, the visual acuity of some hawks and eagles reaches a value at least eight times that of man" (1943, p. 662). It must be said at once that this statement could not possibly be justified on the most extreme assumptions. And, in fact, Walls' analysis is oversimplified in its neglect of aberration, which is so great that the static acuity of the central fovea is in all probability substantially less than it would be if there was no refraction at the vitreo-retinal boundary (Pumphrey, 1948). It is significant in this connection that the profile of the *temporal* fovea of *Aquila* is very shallow and the effect of refraction negligible; for the temporal fovea is used binocularly and must, presumably, obey the same conditions as the similarly shallow fovea of man. It may be inferred that where binocular fusion of images is a prerequisite of accurate judgment of distance and speed, the aberration and loss of definition associated with a steep foveal profile cannot be tolerated (fig. 5, *c*, *d*).

The central fovea is not associated with binocular vision, and it must be remembered that a central fovea with a steep profile is found in fish and reptiles as well as birds. Moreover, the high static acuity associated with the anthropoid fovea is probably a late acquisition. Is there a visual function which (in contrast to acuity) will be assisted rather than hindered by foveal refraction? I suggest that there is. Consider the effect of the fovea on the image of an object which is passing across the visual field with a constant angular velocity. While the image is traveling over the fovea, the effect of refraction is to change momentarily its apparent course, its apparent size and its apparent shape. It is reasonable to suppose that the saliency of the object's movement is thereby increased, just as to human eyes the saliency of movements viewed through a defective piece of window glass is increased. Conversely, foveal fixation of moving objects against a featureless background should be facilitated. As aircraft watchers well know, aircraft vanish into the distance not because they have really become invisible to foveal vision, but simply because the fovea loses them owing to inadequate fixation, and, once lost, the chance of picking them up again is remote. I suggest that the "phenomenal acuity" attributed to birds is simply a phenomenal power of fixation to which the geometrical form of the fovea contributes, or a phenomenal ability to detect angular movement in the visual field, to which again foveal refraction is contributory. There is no evidence of extraordinary acuity in birds which cannot equally well be attributed to one or other of these alternatives; there is no evidence that a distant moving object which is responded to is therefore resolved in the physical sense; there is no evidence that birds respond at all to a stationary object at distances such that the human eye cannot recognize its nature.

Though it may be difficult to prove experimentally that the above inter-

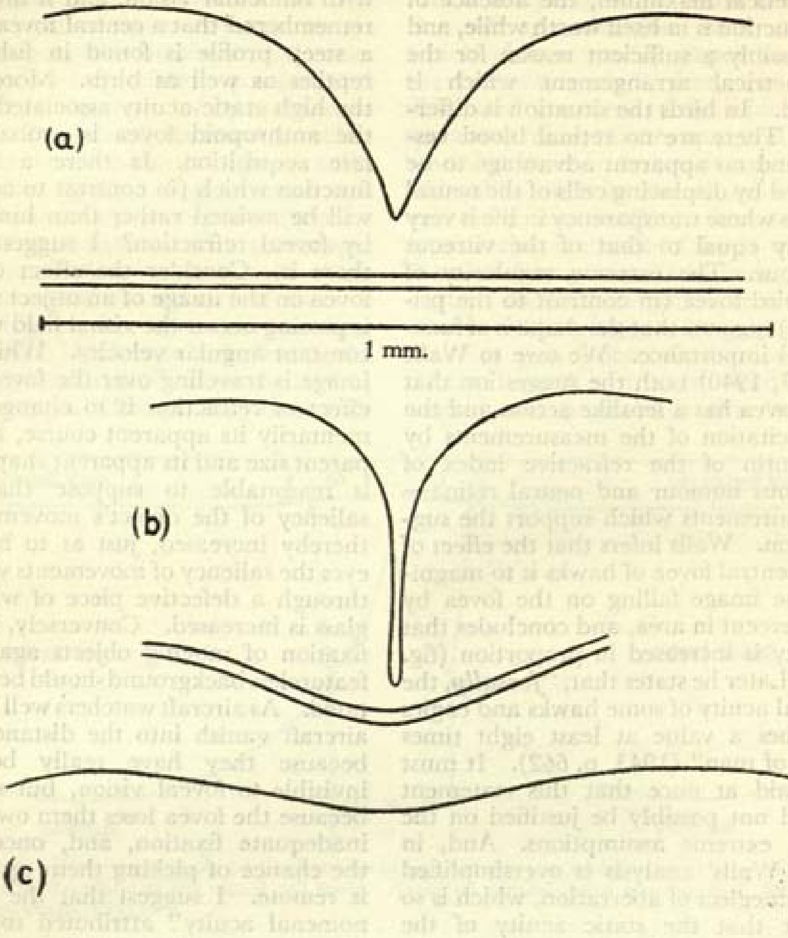

FIGURE 5.—*a*, central fovea of *Aquila chrysaetus*. (After Polyak.) *b*, central fovea of kingfisher. (After Kolmer; no scale given by author.) *c*, temporal fovea of *Aquila*. *d*, fovea of man.

pretation of the function of the steep-sided fovea is correct, it is at least consistent with the current view that detection of movement is a more primitive visual function than interpretation of static detail, for the piscine and the reptilian foveae resemble the typical avian central fovea much more closely than the primate fovea; and it also affords a rational explanation of the extreme steepness of profile of the central fovea of kingfishers, (fig. 5 *b*), which is manifestly incompatible with Walls' theory.

A central fovea is present in most avian retinae with a well-marked central area. A temporal fovea is also present in nearly all birds which pursue moving prey in the daytime—hawks, kingfishers, shrikes, swallows, terns, etc.—and in the hummingbirds, whose feeding habits necessitate a very nice adjustment of hovering flight (pl. 2, lower left). And in all these birds, as has been said, it is so situated that the image of an object ahead is formed on the temporal foveae of both eyes similtaneously (fig. 6). It is very probable that these birds rely entirely on the degree and rate of convergence of the eyes in achieving the fine judgment of the distance and relative speed of their prey which they obviously possess. To achieve the necessary overlap of the visual fields, their eyes are directed more forwardly than is commonly the case for birds, with a consequent sacrifice of the ability to "see behind," which most birds with laterally directed eyes retain. It is noteworthy that owls, which have an even larger binocular field than hawks, have eyes which are rigidly fixed in their sockets and quite incapable of convergence, but here the retina is of the rod-rich nocturnal type and the temporeal fovea is vestigial or absent. (There is no area or central fovea.)

This is a convenient place to comment on one profound difference between the vision of birds and man.

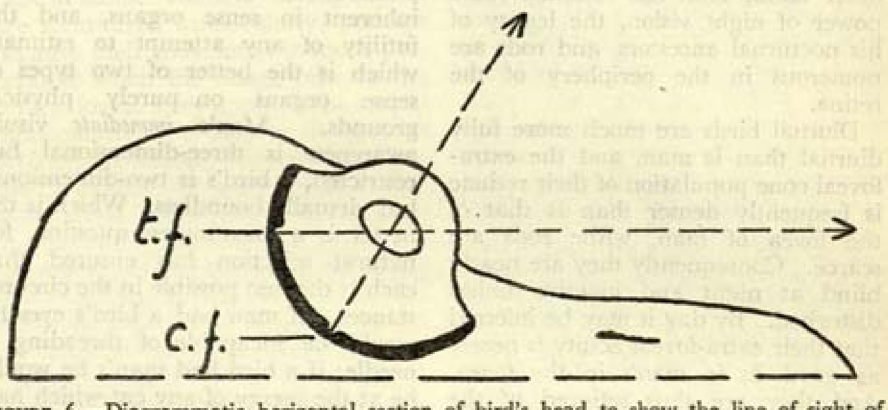

FIGURE 6.—Diagrammatic horizontal section of bird's head to show the line of sight of temporal and central foveae.

Man is fully binocular, his eye movements are conjugate and extensive and his visual field (at daylight intensities) is being continually scanned as these movements cause successive small areas of the field to be fixated foveally by both eyes. Though vision appears to be continuous, sensation is, in fact, almost completely suppressed during these scanning movements, and is only experienced in the intervals when the eye is stationary. (It is impossible to see one's own eyes moving in a mirror.) This suppression is probably necessary to prevent confusion between movement of the image across the fovea due to eye movement and movement of the image due to movement

of the object itself. Compensatory reflexes of the eye muscles ensure that binocular fixation is unaffected by movements of the head. The resolving power (acuity) of the human eye outside the fovea is poor, and the overwhelming importance of foveal vision to man is indicated by the fact that the area of the optical part of the brain concerned with vision by the fovea and its immediate neighborhood is many times larger than that devoted to the whole of the rest of the retina. It is stereoscopic foveal vision which gives solidity to the visual field and makes accurate judgment of distance possible. On the other hand, man has retained some power of night vision, the legacy of his nocturnal ancestors, and rods are numerous in the periphery of the retina.

Diurnal birds are much more fully diurnal than is man, and the extrafoveal cone population of their retinae is frequently denser than is that of the fovea of man, while rods are scarce. Consequently they are nearly blind at night and inactive unless disturbed. By day it may be inferred that their extra-foveal acuity is nearly as good as is man's in the fovea. And they are thus relieved of the necessity of scanning the visual field bit by bit to build up a detailed picture, though intense scrutiny of objects of special interest with the central area of one eye or the other is achieved by movements of the whole head. And the detailed picture extends typically all around the horizon, for there is frequently an appreciable posterior as well as an anterior overlap of the monocular fields. This all-around detailed picture cannot have the stereoscopic solidity or the quality of distance inherent in our own visual images. It is of some interest to enquire how birds get along without this quality, and the answer seems to be that distance enters into avian vision with the same element of successiveness with which detail enters into human vision. For man, the distance element enters into every glance, but the appreciation of detail of the field has to be built by a succession of glances from the same point and directed to different parts of the field. For the bird, detail enters immediately into every glance, but the appreciation of distance has to be built up by a succession of glances from different points toward the same point of the field.

This will, perhaps, seem a rather prolix way of saying that monocularity compels birds to employ the familiar method of parallax in estimating distance. But it does emphasize the element of compromise inherent in sense organs, and the futility of any attempt to estimate which is the better of two types of sense organs on purely physical grounds. Man's *immediate* visual awareness is three-dimensional but restricted, a bird's is two-dimensional but virtually boundless. Which is the better is a meaningless question, for natural selection has ensured that each is the best possible in the circumstances. If man had a bird's eyes he would be incapable of threading a needle; if a bird had man's he would be at the mercy of any cat which had the sense not to attempt a frontal attack.

There is a good deal of evidence that both time and movement are necessary for the bird's visual image to acquire a three-dimensional character. Small birds are frequently road casualties, but they are almost always overtaken on the ground. Once they have started to fly they are astonishingly apt at avoiding collision, and it is at least a plausible suggestion that they are so frequently run over because it is not till they have started to move that the nearness and speed of a vehicle are appreciated. Anyone who has watched a robin feeding will have noticed that it scrutinizes an insect monocularly from at least two places before pecking and eating it. During the peck the

insect is presumably viewed binocularly, and the action is controlled by a distance appreciation based on the amount of accommodation required to bring the image of the insect into focus; but it is likely that the parallax estimate is necessary before the head can safely be brought into position for a peck, and that the successive scrutinies are not due to uncertainty about the edibility of the food.[4]

As has already been indicated, monocularity is considerably modified in those diurnal birds which pursue moving prey, but even in these binocular fixation appears only to occur as a response to a moving object which is close at hand. Remote moving objects are scrutinized monocularly, perhaps because their movement is more perceptible when the image falls on the central fovea. Prey appear to be sought monocularly, and only in the pursuit is binocular fixation brought into play. But although we may suspect that avian vision is fundamentally based on monocularity, operations in which the beak is involved—pecking, preening, nest building, and so forth—have ensured that there was always a use for the anterior binocular field, and that the potentiality of a more highly developed binocularity was always latent. When it emerges, as, judging by the occurrence of a temporal fovea, it has done independently in many remotely related birds, it does so in strict conformity with the requirements of the bird's habits, and would, presumably, subside again if the abandonment of a raptorial career rendered it unnecessary.

VISUAL ACUITY OF BIRDS

It is known that the foveal acuity of man is very close to the maximum physically possible. The imperfection of the image formed by the lens system and the coarseness of grain of the retina individually impose limits on what the eye can resolve, but it is reasonable to expect these limits to be the same, for otherwise either the retina or the dioptric system would be better than it need be, contrary to the law of parsimony that natural selection rigorously enforces. It is found in fact that two self-luminous points such as stars can in the best conditions be seen as separate when their angular separation is more than (but less than twice) the angular separation of two adjacent cones in the fovea, which is about 30 seconds of arc. Moreover, human acuity is somewhat improved by the use of monochromatic illumination and is diminished by a decrease in pupil width. The former eliminates chromatic aberration and the latter increases the extent of the diffraction pattern which forms the image of a point in the field, so we may conclude that both chromatic aberration and diffraction are limiting factors in the human eye. We find however, that in the central fovea of buzzards the effective angular separation of the cones is only about one-third that of the cones in the human fovea. Whether the bird fovea is concerned principally with discrimination of movement or principally with discrimination of detail, in either event the high cone-density must be supposed to be of functional value. And its advantages can only be realized if the dioptric system is improved proportionately, that is to say, the aperture—the ratio of pupil diameter to focal length—must be about three times the aperture of the human eye and, in spite of this, there must be a proportionate decrease in the effect of chromatic aberration.

The shape of the bird eye makes the necessary pupil width quite possible, and though diurnal birds show pupillomotor reflexes (contractions of the pupil in response to sudden increases in illumination), the contractions are not maintained as they are in man, and the

[4] I am indebted to R. E. Moreau for the information that an egret, feeding on insects on the ground, also appears to make several parallax estimates before pecking.

pupil is commonly seen to be widely open in bright sunlight. But the wide pupil by itself would emphasize chromatic aberration, and we have to look elsewhere for a means of reducing its effect. A possible answer to the problem lies in the pigmented oil droplets which have been known for many years to be present in the cones of birds; and these droplets are so situated that light passes through them to reach the light-sensitive terminal segment of the cone. They are generally red and yellow in diurnal and colorless in nocturnal species, the proportion varying both with the species and with position in the retina, and a very plausible explanation of their distribution has been developed by Walls and Judd. The relevant point to the present argument is that the cones of the fovea apparently always contain yellow droplets, and only yellow droplets; so here we have a device which seems capable of absorbing the blue and to a lesser extent the red ends of the visible spectrum, and so suppressing the chromatic fringes which would otherwise mar the image.[5] The presence of the yellow droplets does not, of course, mean that the bird is colorblind, even for foveal vision, for it is not an absolute freedom from chromatic aberration which is the target. The absorption of the blue and red is, presumably, nicely calculated to permit of full use of the foveal cones in resolving detail with the least possible sacrifice of hue discrimination.

We may conclude that birds with the keenest vision are potentially capable of an acuity two to three times that of man.

COLOR VISION

The mechanism of color vision is still so little understood in man that no purpose would be served by a general discussion here. The fact which seems to be established by the best experimental work is that there is very little difference between the color vision of birds and man. The ratio of luminosity to wave length for pure spectral colors, and also the number of distinguishable hues in the spectrum, is not significantly different, which is a little surprising since the work of Watson (1915) and, later, Lashley (1916) was done on the bantam, whose retina is rich in cones with red oil droplets.[6] It must be presumed that there are still enough cones without colored droplets in the retina to register blueness unimpaired. No method has been developed for assessing foveal color vision alone in birds.

Although the limits of color vision seem to be the same for man and birds, it is likely nevertheless that color sense plays a more emphatic part in the visual sensations of diurnal birds than of man simply because of the density of cones in the peripheral retina. If a man looks at a distant part-colored object, such as a flag flapping against the sky, at first directly and then at an increasing angle, he finds that at 20° the individual colors can no longer be distinguished and the hue of the flag is uniform though inconstant. At 30° there is no sensation of hue whatever and the flag is just a dark moving object. This loss of color definition must be attributed to the dilution of cones with rods in the periphery of the human retina, and consequently it will not occur in the most completely diurnal birds, which will see hue as well as detail in its full emphasis over the whole visual field.

MOVEMENT PERCEPTION

If the eye can be said to have a primitive or intrinsic function, that function is undoubtedly the perception

[5] It is still an open question whether the yellow macular pigment does or does not extend over the central part of the *human* fovea. If it does we have here another interesting example of convergence between the human and avian eye.

[6] Despite this work, many students of bird behavior are convinced that birds do not see as far toward the violet end of the spectrum as we do.

of movement.[7] It is movement to which the most primitive eyes respond, and sensitivity to movement remains in eyes so degenerate that all other attributes are lost. Unfortunately it is an exceedingly difficult function to reduce to definition or measurement, but some aspects of it are obvious enough. If a stationary field is viewed with a stationary eye, a movement of a small object in that field will result in a change in illumination of a small part of the retina, while the excitation of the rest of the retina remains constant. Whether the movement is seen as movement or not depends, therefore, not only on the threshold of the sensory elements for change and for rate of change of illumination, but also on the presence of a stationary but variegated background. Consequently a moving object may fail to be seen as moving (*a*) because it is too small or too good a match to the background to be seen at all, (*b*) because it is moving too slowly or too fast, or (*c*) because the background, or part of it, is also moving, or (*d*) because the background has no landmarks. All these conditions are quite obvious and familiar, but the background difficulty is much less acute for man, most of whose activities require him to look horizontally, than it is for birds, which often have to look up at a clear sky or down at uniform pasture and moor and sea. In such cases there is nothing to hold the eye so that the retina can settle down to a steady state in which the changing excitation due to movement of an object will be salient. Yet there is abundant evidence that birds as a whole are immensely more successful than man at detecting movement.

A tentative but fascinating explanation of this faculty was offered by Menner (1938) as a result of his examination of the pecten of a number of birds, supplemented by one experiment. The primitive function of the pecten is undoubtedly nutritive. Birds do not have, and probably could not tolerate without a substantial loss of acuity, the network of blood vessels which spread over and nourish the inner layers of the mammalian retina. Instead they have the pecten, a more or less conical foliated structure whose base covers the "blind spot" at the entry of the optic nerve and whose apex is directed out toward the pupil. The pecten is richly supplied with blood vessels, and it is presumed that nutritive substances diffuse through the vitreous humour between it and the retina. But though a number of fantastic suggestions have been made about possible subsidiary functions, no one before Menner seriously thought of it as anything but a nuisance in the dioptric system. Menner, however, proved that not only do the foliations throw shadows onto a functional part of the retina but that the extent of foliation, and consequently of the shadows, is directly related to habits. They are most extensive in hawks; diurnal insectivorous birds come next, then grain feeders, with nocturnal birds easily last (fig. 7). Menner inferred that the pecten played some part in the detection of movement. He directed a camera at the sky in which some high-flying swifts were circling, and, inspecting the image of the sky on the ground-glass focusing screen, he was unable to detect any trace of the images of the moving swifts. When a model of a hawk's pecten was stuck on the inner side of the ground glass, he found he could then easily detect the images of birds.

The principle of this remarkable observation has been confirmed and extended by Crozier and Wolf (1943) and there is no doubt of its reality, but the theory is still very incomplete. It is known, however, from other

[7] Movement here refers to movement across the line of sight. Perception of movement along the line of sight is a very much less general accomplishment. To avoid ambiguity, it may be necessary to point out this section is concerned with *initial* detection of movement. The case is distinct from the perception of movement in an object which has already been fixated by the central fovea, a type of movement perception discussed above.

experiments, that cone summation must occur at some level, for the threshold for brightness discrimination (at high illuminations as well as at low) is higher the smaller the area of the retina stimulated. Now the *mean* illumination of the retina when the eye is looking at a bright sky is not changed by movement of a dark falls in the mean illumination. It is therefore quite possible that the pecten is effective in increasing contrast, but it is doubtful, perhaps, whether it is proper to speak of the effect as enhancing perception of movement. The contrast is improved equally whether it is the object or the eye which moves, and the improvement

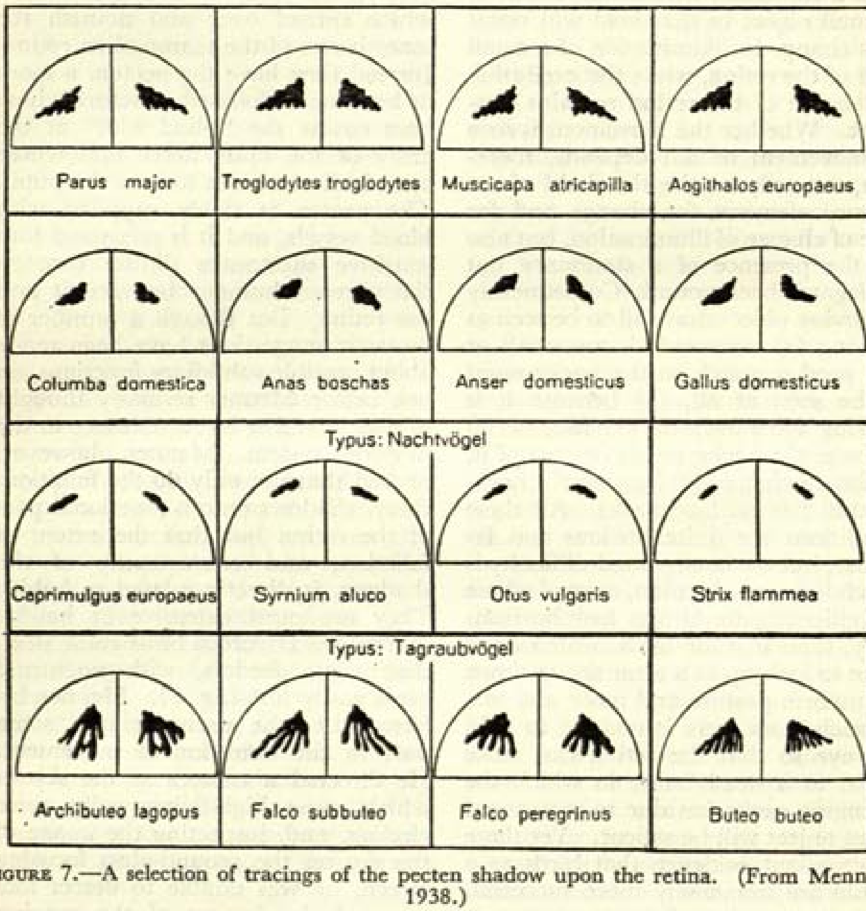

FIGURE 7.—A selection of tracings of the pecten shadow upon the retina. (From Menner, 1938.)

object, such as a swift, within the inspected area provided the optical path is unobstructed. If, however, a series of shadows is cast on the retina by an obstruction, it is clear that the mean illumination will be a maximum when the image of the object coincides with one of the shadows. Consequently movement of the object across the field will cause successive rises and is likely to be most marked when the background is so neutral and featureless that there is no fixation point to keep the eye still.

NOCTURNALITY

Nocturnal birds have eyes specialized for night vision, though to a less extent than those of completely noc-

turnal mammals. The increase in sensitivity is achieved at the sacrifice of many of the features which increase the resolving power of the diurnal eye. In the retina rods are predominant and cones few, the oil droplets are colorless or absent, and there is no fovea or only a vestige. The curvature of the cornea is less and its area greater, and the lens approaches a spherical shape and retreats toward the fundus of the eye (fig. 8). The apparatus of accommodation is degenerate. The effect of all these changes in dimensions is to produce a substantially smaller, and therefore, brighter (though more aberrated and distorted) image.

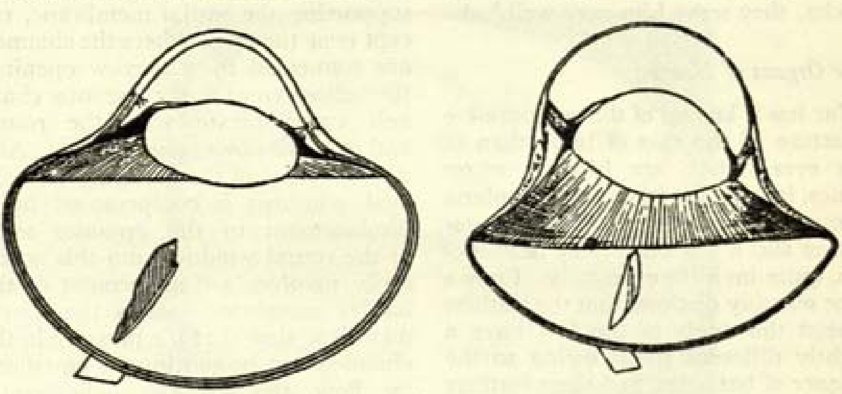

FIGURE 8.—Horizontal sections of the left eyes of the diurnal honey buzzard *Pernis apivorus* and the nocturnal Australian frogmouth *Podargus strigoides*. (After Franz, 1934.)

A typically nocturnal adaptation in mammals is the formation of a tapetum. In diurnal eyes the retina is backed by the densely pigmented chorioid layer of cells whose function is to absorb light not absorbed by the retina, and so prevent blurring of the image by scattering, the effect known to photographers as halation. Nocturnal eyes can usually not afford such a loss of radiant energy in the pigment which is replaced by a mirror called the tapetum over at least part of the fundus of the eye, so that light which is passed unabsorbed through the retina in the first instance is reflected back into it. It is the presence of a tapetum which gives rise to the brilliant "eyeshine" of cats caught in a car's headlights. Owls rather surprisingly have no tapetum,[8] but the nightjar family, which show brilliant eyeshine, presumably have. Apart from these two families, nocturnal habits are rare and sporadic in birds. The kiwi is exceptional in this, as in so many other ways, but its eyes are considered to be very poor. Alone among birds it is believed to have a keen sense of smell and to find its food thereby.

In spite of all that has been said about the night vision of owls, it does not seem possible that the most nocturnal of them hunt by sight alone.

[8] The only use of a tapetum is to give the retina a second chance, and it is only when the retina itself is relatively inefficient that a tapetum is worth while. If, for example, the rods transmit 1 percent and absorb 99 percent of the light falling on them, a tapetum which would allow them to absorb a further 99 percent of the 1 percent which escaped them at the first transmission would not be economic since it would increase the efficiency by only 1 percent. If, however, the rods only absorb 50 percent at the first transmission and a further 50 percent of the light reflected back into them by a tapetum, then if the tapetum is a perfect reflector, it will increase the efficiency by 50 percent, which is worth while.

The terminal segments of the rods in the owl's retina are known to be exceptionally long and, therefore, may possibly absorb so much incident light that a tapetum would be a luxury.

The extent to which an owl's eye is better than man's at night is roughly calculable. It is unlikely that the sensitivity of the owl's eye is more than 100 times that of the fully dark-adapted human eye, so that an owl perhaps sees nearly as well by bright starlight as man by a bright full moon. But though bright moonlight may look light enough to play tennis by, it is not so in fact, and it is probable that an owl's chances of finding a mouse on a dark night by sight alone are nil. If his eyes enable him only to avoid collision with bushes and other obstacles, they serve him very well.[9]

The Organs of Hearing

Far less is known of the comparative structure of the ears of birds than of the eyes. They are hidden, secret things, lacking the large external pinna of most mammals and, except in ostriches and a few other very bald species, quite invisible externally. Only a close scrutiny discloses that the feathers behind the angle of the jaw have a slightly different sheen owing to the absence of barbules; and these feathers must be turned forward before the small external aperture of the outer ear can be seen.

The avian ear is divisible, like the human, into outer, middle and inner parts (fig. 9). The cavity of the outer ear, the external meatus, is terminated by the tympanic membrane. The middle ear cavity communicates with the pharynx through the Eustachian tube and with the inner ear by two membrane-covered openings, the oval and round windows. The oval window is almost completely filled by the foot plate of the columella, a bone which, with its cartilaginous extension, the extra-columella, communicates the movements of the tympanic membrane to the liquid perilymph of the inner ear.

The auditory part of the inner ear, the cochlea, resembles that of man in its general plan, though it is proportionately much shorter and is straight, or nearly so, instead of being rolled into a tight spiral. It is divided into two channels by cartilaginous shelves supporting the basilar membrane, except near the apex, where the channels are connected by a narrow opening, the helicotrema; and these two channels communicate with the round and oval windows respectively. Any displacement of the perilymph at the oval windows is compensated by a displacement in the opposite sense at the round window, and this necessarily involves a displacement of the basilar membrane unless the movement is so slow that the pressure in the channels can be continually equalized by flow through the helicotrema.

On the basilar membrane are ranged the hair cells, which are believed to be the actual receptors for sound. They carry fine processes which terminate on or in the tectorial membrane and are consequently distorted or stretched when the basilar membrane is displaced. The hair cells are innervated by nerve fibers from the cochlear ganglion. The whole of this sensory apparatus is separated from the perilymph by the basilar membrane below and the tegmentum vasculosum[10] above.

The basilar membrane contains transverse fibers which increase regularly in length and probably decrease in tension from the outer (basal) end of the membrane to the apical end. It is believed that, as in man, these fibers

[9] The view of Vanderplank (1934) that owls "see" their prey as self-luminous sources of infrared rays has received considerable publicity. It may be noted that Hecht and Pirenne (1940) found that the pupillomotor response of the eye of *Asio wilsonianus* to difent wave lengths yields a curve identical with the human scotopic brightness curve. Matthews and Matthews (1939) have shown that the eye of *Strix aluco* (Vanderplank's species) does not transmit infrared, and that no electrical response follows exposure to infrared. It may be concluded that Vanderplank's theory has no foundation in fact.

[10] The tegmentum vasculosum corresponds roughly in position to Reissner's membrane in the mammalian cochlea but incorporates the stria vascularis.

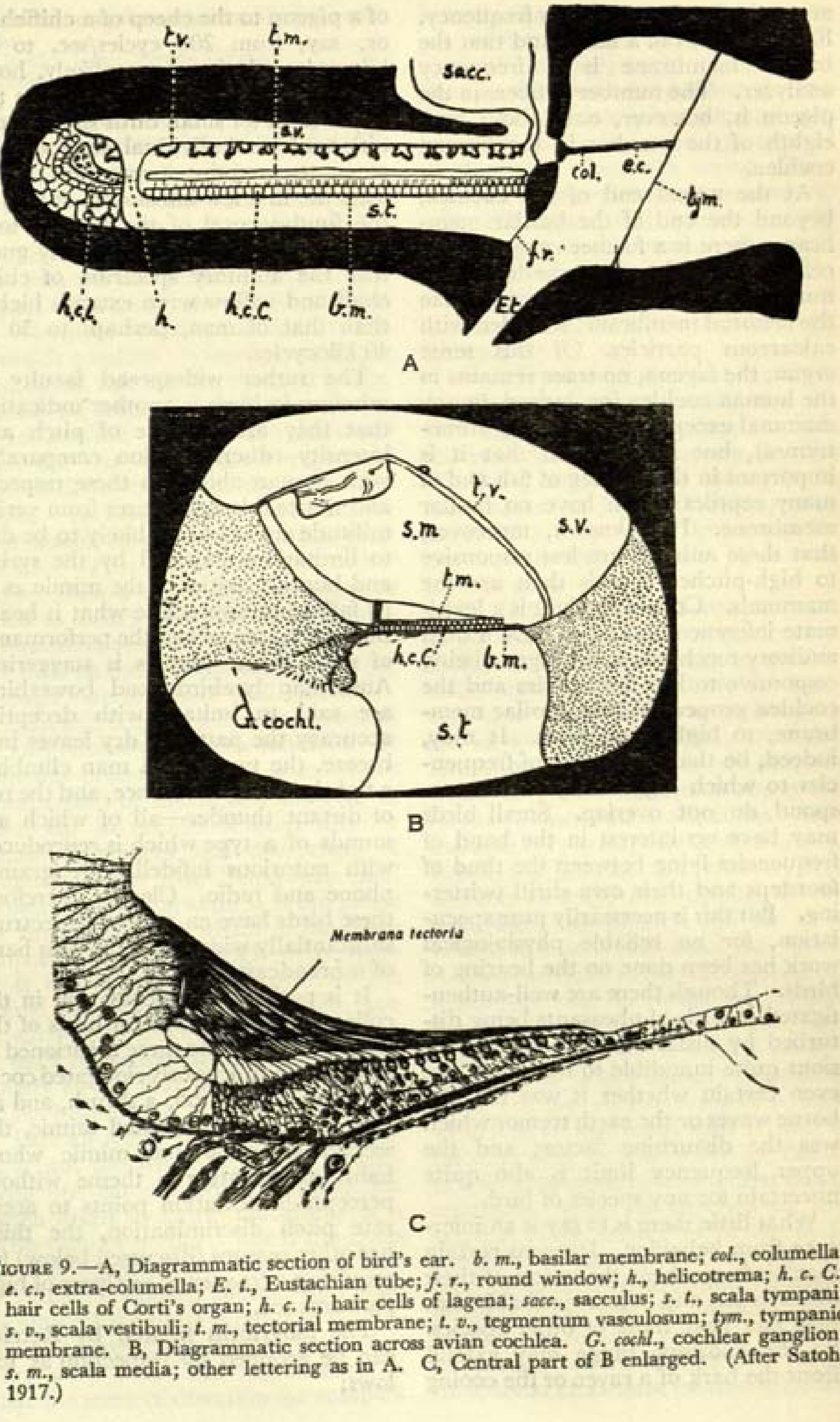

FIGURE 9.—A, Diagrammatic section of bird's ear. *b. m.*, basilar membrane; *col.*, columella; *e. c.*, extra-columella; *E. t.*, Eustachian tube; *f. r.*, round window; *h.*, helicotrema; *h. c. C.*, hair cells of Corti's organ; *h. c. l.*, hair cells of lagena; *sacc.*, sacculus; *s. t.*, scala tympani; *s. v.*, scala vestibuli; *t. m.*, tectorial membrane; *t. v.*, tegmentum vasculosum; *tym.*, tympanic membrane. B, Diagrammatic section across avian cochlea. *G. cochl.*, cochlear ganglion; *s. m.*, scala media; other lettering as in A. C, Central part of B enlarged. (After Satoh, 1917.)

are each tuned to a distinct frequency, like the strings of a harp, and that the basilar membrane is a frequency analyzer. The number of fibers in the pigeon is, however, only about one-eighth of the number in the human cochlea.

At the apical end of the cochlea, beyond the end of the basilar membrane, there is a further range of hair cells whose hairs are embedded in a mucoid cap or *cupola*. The cap, unlike the tectorial membrane, is loaded with calcareous particles. Of this sense organ, the lagena, no trace remains in the human cochlea (or, indeed, in any mammal except the egg-laying Monotremes), but it is known that it is important in the hearing of fish and of many reptiles which have no basilar membrane. It is known, moreover, that these animals are less responsive to high-pitched sounds than are the mammals. Consequently it is a legitimate inference that birds have a dual auditory mechanism, the lagena being responsive to low frequencies and the cochlea proper, with its basilar membrane, to high frequencies. It may, indeed, be that the ranges of frequencies to which lagena and cochlea respond do not overlap. Small birds may have no interest in the band of frequencies lying between the thud of footsteps and their own shrill twittering. But this is necessarily pure speculation, for no reliable physiological work has been done on the hearing of birds. Though there are well-authenticated records of pheasants being disturbed by distant gunfire and explosions quite inaudible to man, it is not even certain whether it was the airborne waves or the earth tremor which was the disturbing factor; and the upper frequency limit is also quite uncertain for any species of bird.

What little there is to say is an inference from behavior. It seems certain that birds can hear the voices of their own species, and at least probable that they can hear those of other species. So the auditory range may extend from the bark of a raven or the cooing of a pigeon to the cheep of a chiffchaff or, say, from 200 cycles/sec. to 10 kilocycles. It is most unlikely, however, that 10 kilocycles represents the upper limit for small birds since recognition of an individual song or call seems to require perception of at least the first few harmonics as well as the fundamental of the highest tone in the song. We may plausibly guess that the auditory spectrum of chiffchaff and willow wren extends higher than that of man, perhaps to 30 or 40 kilocycles.

The rather widespread faculty of mimicry in birds is another indication that they are capable of pitch and intensity discrimination comparable with human ability in these respects, and noticeable departures from verisimilitude are at least as likely to be due to limitations imposed by the syrinx and buccal cavities of the mimic as to its failure to appreciate what it hears. But as a matter of fact the performance of some exotic mimics is staggering. Australian lyrebirds and bowerbirds are said to imitate with deceptive accuracy the patter of dry leaves in a breeze, the twang of a man climbing a tightly strung wire fence, and the roll of distant thunder—all of which are sounds of a type which is reproduced with notorious infidelity by gramaphone and radio. Clearly, therefore, these birds have an auditory spectrum substantially wider than the pass band of a broadcast receiver.

It is perhaps significant that in the collection of labryinths of birds of the late A. A. Gray the three mentioned as having a conspicuously elongated cochlea were a cockatoo, a thrush, and an owl. The first is a noted mimic, the second an occasional mimic whose habit of repeating a theme without perceptible deviation points to accurate pitch discrimination, the third has other reasons (discussed below) for requiring a frequency analyzer of high performance.

The labyrinths figured by Retzius can be grouped by inspection as follows:

Cochlea conspicuously long (and curved): *Bubo*.

Cochlea long: *Turdus, Columba*.

Cochlea average: *Vanellus, Scolopax, Cypselus, Nucifraga*.

Cochlea short: *Gallus*.

Cochlea very short: *Anser, Mergus, Haliaëtus*.

If we exclude the owl, we can perhaps imagine a correlation between length of cochlea and musical ability in this series.

A little bit more is known of another aspect of hearing, the ability of birds to determine the direction from which sound is coming. It might be thought that birds, lacking the external pinna, would be severely handicapped, but reliable work on the hen indicates that she can locate the cheeping of her chicks within 2° in the horizontal plane. Incidentally, the chicks are just about as good at locating their mother. This performance is rather better than a dog's and not quite as good as a cat's performance in similar circumstances. It is substantially better than an inexperienced man can do, though man improves with practice.

Man's directional sensitivity to sound is an extremely complex function. It depends primarily on an unconscious comparison of the signals arriving at each ear in respect of both time or phase differences and differences of intensity. For low frequencies and noises of short duration it is the phase or time difference which is the more important, and for high frequencies it is the intensity difference. If the sound lasts long enough and the man is allowed to move his head, he turns it until the sound paths to his ears are nearly equal, and in this position can make his most accurate estimate.

This all seems obvious enough, but it is not the whole story, for a man with one ear plugged is quite at sea when asked to locate the source of a pure tone or a click. But if the noise is both complex and continuing like a rattle or human speech, and particularly if the noise is familiar to him, he can locate it nearly as well as if both ears were free. The explanation is that the sense of direction for complex sounds depends rather intimately on an analysis of the relative intensities of the frequency components. Because the head casts a sound shadow which is more complete for high frequencies than low, the perceptual character of a complex sound differs with the angle at which it reaches the ear. If it is familiar, it is unconsciously compared with the memory of what it should sound like when coming from directly in front, and the head is moved until the sound heard corresponds with the memory.

There is no evidence that birds are capable of monaural localization. In fact Englemann's experiments with the hen indicate the contrary, but the possibility must not be ignored. In any case it is likely that frequency analysis is even more important in direction finding for some birds than it is for man.

The hen, like dog and man, appears to be almost incapable of localization in the vertical plane. Man invariably refers an unfamiliar noise to the horizon, and has to learn to look up to see an aircraft. It is likely that this limitation is inherent in all animals whose ears are symmetrical about the median plane of the head, a class which includes very nearly all the vertebrates. It has long been known, however, that the ears of many owls display a very remarkable asymmetry. So far as is known it is only the outer ear which is asymmetrical. And on the whole it is in the most nocturnal species that the asymmetry is most marked. Before discussing these structural peculiarities it is illuminating to consider what are the requirements of a bird which is so nocturnal that it has to find its prey by ear while in flight. It obviously must possess a directional sensitivity which is effective in the vertical plane as well as in the horizontal, and this is quite obviously impossible if the ears are mirror images of each other and the median plane of the head remains vertical. It must be further assumed that the bird's directional clues must be derived from

sounds of short duration—transient rustles and squeaks which do not last long enough for the bird to make searching movements with its head.

In order to locate such sounds unambiguously with two ears only it appears, from theoretical considerations, that the following minimum conditions must be satisfied:

(1) The sound must be complex and the ears competent to resolve it into at least three bands of frequency in such a way that independent comparison of the signals arriving at the two ears is possible in each band.

(2) The two ears must have a direction of maximum sensitivity which is different for each band and is different for the left and right ear for at least two of the bands.

The exceptional length of the owl's cochlea and the prevalent asymmetry of their external ears suggests that these conditions are in fact met, though the second condition is fulfilled in different ways in different genera.

Birds are prevented by aerodynamic considerations from using external baffles like the pinnæ of mammalian ears. Whatever is done must be under the cover of the feathers which insure laminar flow across the orifice of the auditory meatus and subdue the whistling of the wind. We find in *Strix* that the left and right ear cavities are of markedly different sizes and are each nearly closed by opercular flaps, leaving a slitlike orifice which is half as long again on the left as on the right. For wave lengths comparable with the length of the slit the polar diagrams of left and right ears will certainly be different.

In *Asio* the external auditory meatus is enormously enlarged on both sides to occupy the whole of the lateral post-orbital sides of the head. Here the opercular slits are of similar dimensions on the left and right sides. But beneath the opercula the meatus on each side is divided into two compartments by a horizontal shelf, one compartment communicating with the middle ear while the other is blind. On the right it is the upper compartment which is blind and on the left the lower (pl. 3). The effect of the arrangement is to make the relative lengths of the sound paths from the upper and lower extremities of the slit to the tympanic membrane different on the left and right side; so that for wave lengths comparable with the slit lengths the direction of maximum sensitivity will be directed above the horizontal plane for the right ear and below it on the left.

Of the two British species of *Asio*, one, *A. otus*, the long-eared owl, is very nocturnal while *A. flammeus*, the short-eared owl, is largely diurnal, and it has been argued that, because of the similarity of the ears in species with different habits, it is illegitimate to correlate asymmetry of the ears with night hunting. This is a misconception. The asymmetry of the ears indicates that owls are descended from nocturnal ancestors which were forced to rely on their ears for hunting. Even the most diurnal owls have eyes of nocturnal form which must be deficient in daylight compared with those of, say, a hawk. The late Miss Turner's description of the hunting of the short-eared owl does not suggest that the eyes are used. In fact, since the principal prey is the field vole, which at least by day lives in grass tunnels, it is difficult to see how the eyes could be used. It seems certain that the owl locates the prey quite accurately by ear and then rakes through the grass for it with its talons.

Another fully nocturnal species, Tengmalm's owl, shows an asymmetry of the ears which involves extensive distortion of the bony structure of the skull in which the right ear is set above and the left below the midline of the orbits. It is likely that the objective of the asymmetry is the same as in *Asio* and *Strix*, but the descriptions of the soft anatomy which are available are inadequate for certainty.

It will have been noted that there is a sufficient body of knowledge of the avian eye to permit of intelligent spec-

ulation about its performance and the part it plays in determining avian behavior. This is far less true of the ear, which offers a most promising and unjustly neglected field for experiment and observation.

Other Sense Organs

Of the other sense organs, there remains little that is worth saying. The sense of smell is undoubtedly only very moderately developed by comparison with the more gifted mammals. Though birds can be trained to respond to odoriferous substances, such training is very readily disrupted by visual or aural stimuli, which is at least an indication of the relative unimportance of olfaction. It should be noted that there are persistent reports that some birds show evidence of a keener sense of smell than might be expected. These include the carrion feeders, especially the vultures, scavengers like gulls and petrels and, rather surprisingly, the ducks. The literature, which is largely anecodotal, has been reviewed by Gurney (1922) in this journal. Most of the positive evidence brought forward by one authority has been destructively criticized by another. Indeed, in this field critical experiments are almost impossible, because human beings labor under the excessive difficulty of not knowing what to look for. There is no theory of smell which is even moderately consistent with the facts of human olfactory experience, and we can perhaps best sum up the situation for birds by saying we know even less about their sense of smell than we do about our own.

The sense of touch is in a class rather by itself. For one thing it is not a single sense in the way in which sight and hearing are (in vertebrates) single senses; there is no organ of touch, but a multiplicity of organs whose individual responses to stimulation must be centrally integrated before a man can tell a tennis ball from an egg with his eyes shut. For another, though not distance receptors, the organs of touch are complementary to them. Man and the primates learn very much by seeing plus handling and by hearing plus handling, and it is in the skin of the fingers and the muscles and joints of the arms that the sense of touch is most highly developed. We find in the inner skin of the hands numerous sensory end-organs of a type which are rare or absent elsewhere, consisting of a capsule of tissue within which the fiber of a sensory nerve terminates in a coil or web. In other mammals which have no hands but, like the pig and the mole, use the snout for exploratory purposes, we find very similar encapsulated end-organs most numerous in the moist mucosa round the nostrils. In birds similar end-organs are found in the beak and tongue, and though at first sight the horny beak appears unlikely to be a suitable vehicle for a refined sense of touch, the presence of end-organs of this type suggests that it is in fact the part of birds which is tactually the most sensitive. The sensory capsules are most complex and most numerous, so far as known, in the bills of ducks (pl. 4) and geese, and very likely are important for finding food in mud. It does not seem that the histology of the beaks of waders has ever been examined. By contrast the innervation of the feet is scanty (even in the hawks and owls), and they are probably quite insensitive to touch.

Incertae Sedis

This article is about sense organs, and it might be the better part of wisdom for the author to leave it at that and refrain from even passing mention of senses which in some way have a reality and importance for animals in general and birds in particular but which are not, or at least not yet, referable with certainty to special sense organs. These "senses" are the sense of time and the sense of direction; and their relevance to the migratory problems of birds is obvious,

for the minimum requirements for achieving a long and trackless journey are a clock and a compass.

It is curious, and perhaps significant, that, on a small scale, both these senses are connected in human experience with the ear (auditory and nonauditory parts of the labyrinth). It is notorious that the visual mechanism is capable of only an elementary appreciation of time interval. If a man desires to appreciate the time interval between two events he either turns the time interval into a space interval by some stroboscopic or oscillographic device for visual observation or he arranges for each event to give an audible signal and *listens* to the interval; and the second method is, within a limited range, surprisingly sensitive.

On a short scale, too, the normal orientation mechanism of the semicircular canals and utricle in the nonauditory part of the labyrinth tells man not only which way up he is in the absence of visual clues but which way he is turning and how fast. We have, therefore, in the ear and its associated centers in the brain the rudiments of the clock and compass we were looking for.

It is true that these rudiments are very inadequate. They do not hinder civilized man from losing his way in a fog, nor prevent him from estimating quite wrongly the time he spends in a dentist's chair or a tavern. It may, however, be that they are vestiges rather than rudiments. There *are* people who can awake themselves at a specified hour without an alarm clock. There *are* people, generally country folk, in whose lives the points of the compass are a constant frame of reference. The Irishwoman in the railway carriage in Somerville's story "Poisson d'Avril," who said "Move *west* a small piece, Mary Jack, if you please. I declare we're as throng as three in a bed this minute," is a type of an aptitude so common as to be the rule in many districts.

Because we know so little about these "senses" it is still possible to adopt either of two radically different theoretical approaches. The sense of time has been regarded as a sense of interval, for which the reference standard is the solar day. And alternatively, the reference standard has been thought to be inherent and associated in some way with the rate of living of the animal organism. The latter view would make the time sense independent of external stimuli, at least in the warm-blooded birds or animals, and would make biological time akin in a philosophic sense to the thermodynamic time of Eddington and Milne.

In a rather similar way the sense of direction and position has been regarded as either the expression of a kind of dead reckoning for which the starting point is a particular orientation in a known topography or as being based on some kind of internal compass needle. Ising (1945) has made the interesting suggestion that the semicircular canals may be inherently suited to supply the internal compass needle since they are a device by which Coriolis forces might be distinguished from other and generally much larger forces acting on a bird in flight. The physics involved is in a field which is unfamiliar to most people. Any body which moves at constant velocity over the earth's surface will in general have a component of velocity toward the earth's axis of rotation and will in consequence experience a horizontal force normal to its own direction of motion. This is the Coriolis force. It is proportional to the velocity component toward the earth's axis and is therefore zero at the Equator and also for movement in east or west direction. For north or south movement it is a maximum and increases with latitude.

If the body which we have been considering were a bird in level flight at constant speed, the Coriolis force would be equivalent, so far as the bird's receptors were concerned, to a very small linear acceleration sideways, and there would be no way of

disentangling its effect from the other and much larger linear accelerations experienced as the result of wind irregularities, etc. But the effect on a rotating body is different. Consider the special case of a liquid-filled tube (fig. 10) rotating with the earth.

And suppose it also to spin about the axis WE so that at the instant illustrated the north limb is descending. At this instant the liquid in the north limb has its maximum velocity toward the earth's spin axis and that in the south its maximum velocity away from it. In the result the Coriolis force is a couple acting on the liquid causing it to flow around the tube. For a constant rate of spin the Coriolis couple and hence the flow vary sinusoidally, precisely as the e. m. f. and current would vary in a ring-shaped conductor rotating in a magnetic field.

If we now suppose the tube to represent one of the horizontal semicircular canals of a bird, it is evident that if the bird nods its head in the N–S direction a circulating current will tend to occur in the endolymph of these canals while a nod in the E–W direction will have no effect. Moreover the circulation due simply to the inertia of the endolymph when the head nods is limited to the vertical canals.

The Coriolis force could in this way be separated from other forces and could therefore in theory be used as an indication of true bearings. In fact a large-scale working model has

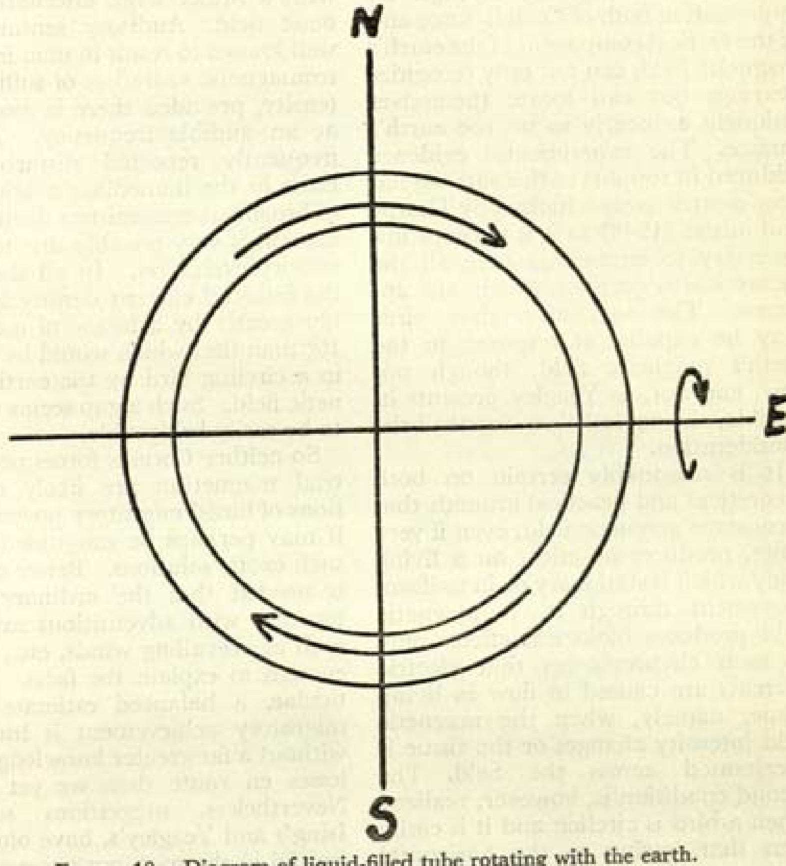

Figure 10.—Diagram of liquid-filled tube rotating with the earth.

been constructed. Thorpe and Wilkinson (1946) have considered whether such a system could operate on a small scale and have concluded that in a bird's labyrinth viscous losses would be large and the Coriolis flow would be less than that due to random thermal agitation.

More recently Yeagley (1947) has surmised that pigeons, through an appreciation both of Coriolis force and of the vertical component of the earth's magnetic field, can not only recognize bearings but can locate themselves uniquely or nearly so on the earth's surface. The experimental evidence adduced in support of this surmise has been destructively criticized by Thorpe and others (1948) so it is perhaps unnecessary to enumerate here all the theoretical objections which are apparent. The suggestion that birds may be capable of response to the earth's magnetic field, though not new, and not, as Yeagley presents it, feasible, is nevertheless worth brief consideration.

It is reasonably certain on both theoretical and practical grounds that a constant magnetic field, even if very large, produces no effect on a living body which is stationary or in uniform movement through it. A magnetic field produces biological effects only in such circumstances that electric currents are caused to flow in living tissue, namely, when the magnetic field intensity changes or the tissue is accelerated across the field. The second condition is, however, realized when a bird is circling and it is easily seen that, owing to the horizontal component of the earth's magnetic field, the current through any small element of volume within the bird will vary sinusoidally through a cycle for each completed circle of flight. Hence if the bird could appreciate the instants of maximum current it could distinguish N. and S. from E. and W. If it could also appreciate the sense of the current it could distinguish the cardinal points uniquely.

As in the case of Ising's theory the plausibility of this kind of mechanism turns on a comparison of the magnitude of the currents likely to be produced in such circumstances with the magnitudes of currents known to have sensory effects. One of the few relevant experiments is that of Magnusson and Stevens (1911) who succeeded in producing visual sensations in man with a rather large alternating magnetic field. Auditory sensations are well known to result in man from electromagnetic radiation of sufficient intensity, provided there is modulation at an audible frequency. And the frequently reported disturbance of birds in the immediate neighborhood of broadcast transmitters during transmission is very possibly due to similar sensory excitation. In all these cases the induced current density is probably greater by a factor of more than 10^5 than that which would be induced in a circling bird by the earth's magnetic field. Such a gap seems too wide to be easily bridgeable.

So neither Coriolis forces nor terrestrial magnetism are likely explanations of birds' migratory powers. And it may perhaps be misguided to seek such exotic solutions. Better evidence is needed that the ordinary senses, together with adventitious assistance, such as prevailing winds, etc., are not enough to explain the facts. In particular, a balanced estimate of the migratory achievement is impossible without a far greater knowledge of the losses en route than we yet possess. Nevertheless, suggestions such as Ising's and Yeagley's, have often been fruitful in the past, not necessarily because they were right, but because the attempt to disprove or confirm them gave an impetus and direction to research which was previously random and fumbling.

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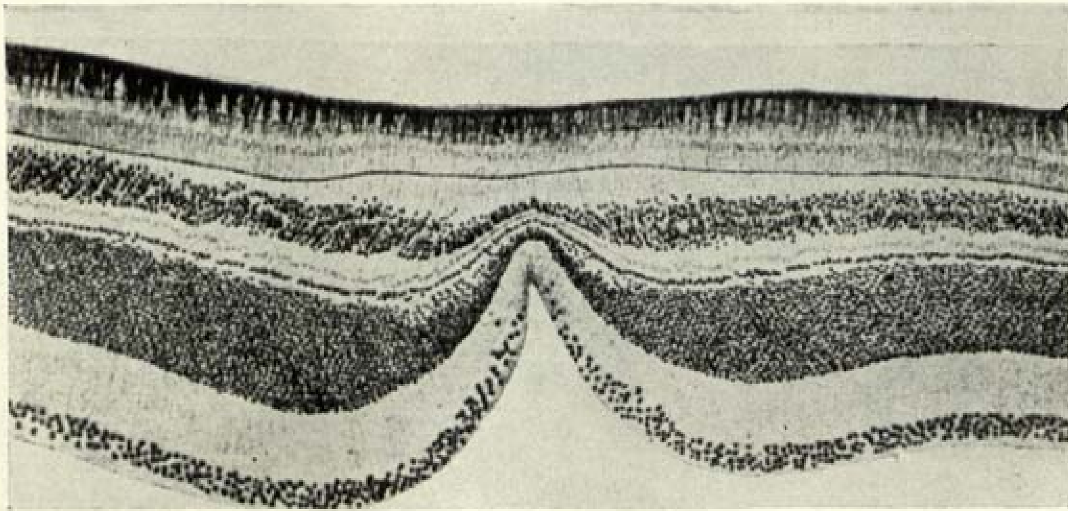
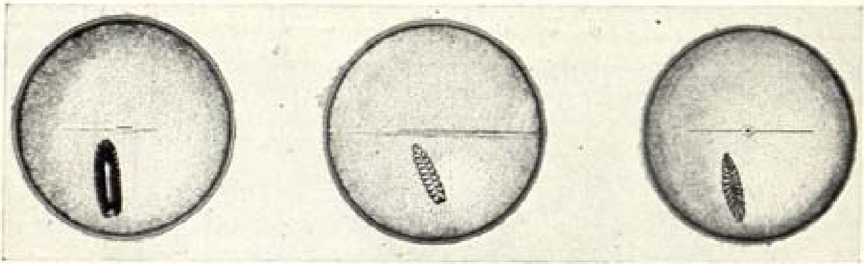
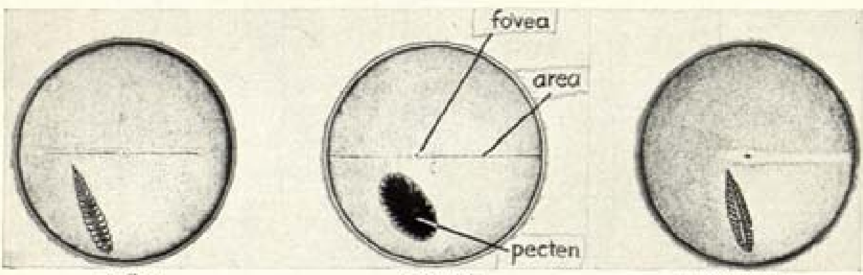


SECTION OF RETINA OF SWALLOW PASSING THROUGH THE CENTRAL FOVEA

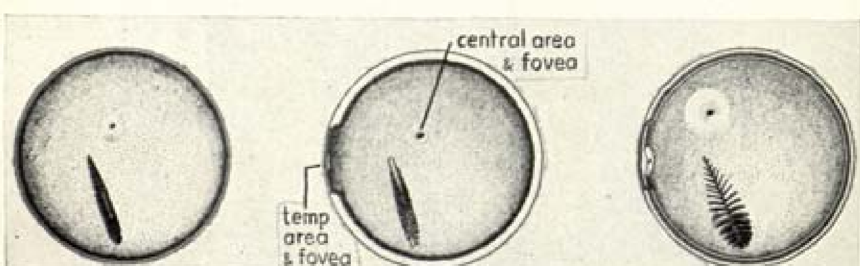
a, pigmented chorioid layer; *b*, layer of the terminal (photoreceptive) segments of rods and cones; *c*, layer of nuclei of rods and cones; *d*, outer plexiform layer (interconnections of rods and cones with bipolar cells); *e*, nuclei of bipolar cells (and also of nerve cells making transverse interconnections); *f*, inner plexiform layer (connections between bipolar and ganglion cells); *g*, nuclei of ganglion cells; *h*, vitreous humour.



1. Herring Gull *Larus argentatus* 2. Shearwater *Puffinus griseus* 3. Great Bustard *Otis tarda*



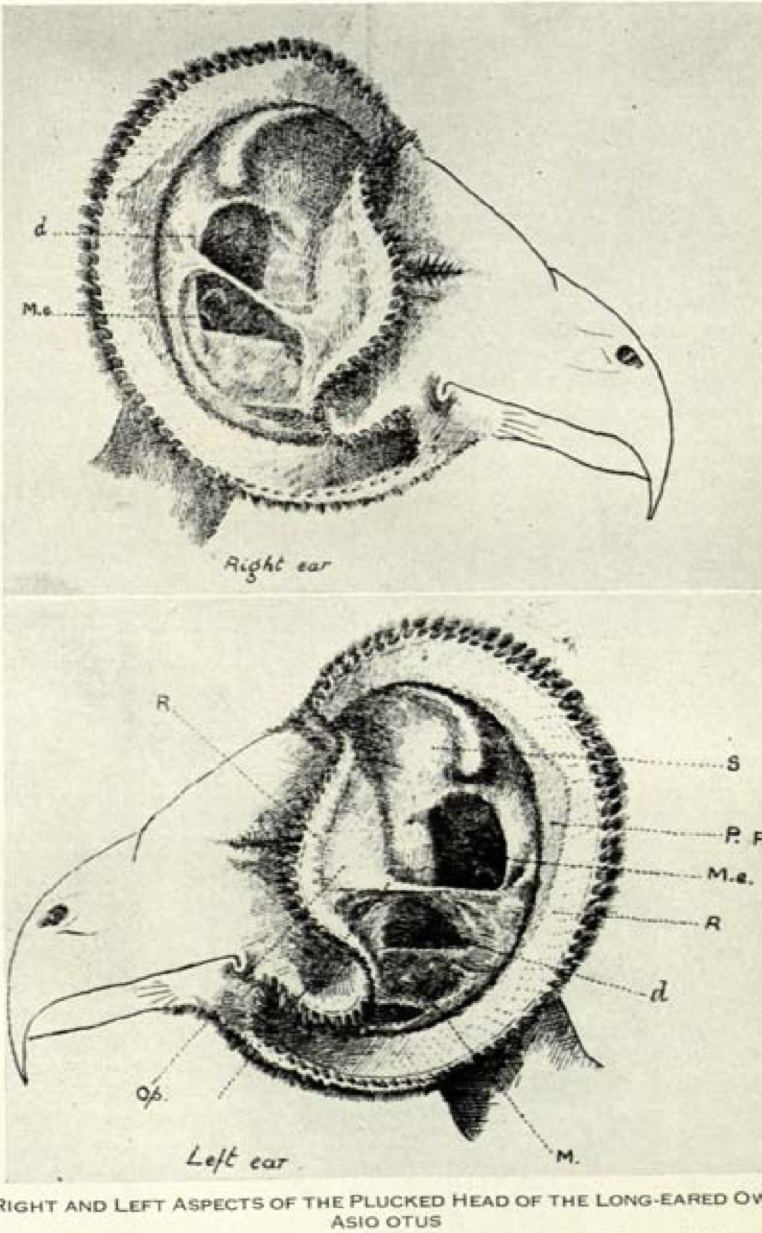
4. Coot *Fulica americana* 5. Ostrich *Struthio camelus* 6. Cormorant *Phalacrocorax penicillatus*



7. Humming bird *Calypte anna* 8. Shrike *Lanius ludovicianus gambeli* 9. Kingfisher *Alcedo atthis ispida*

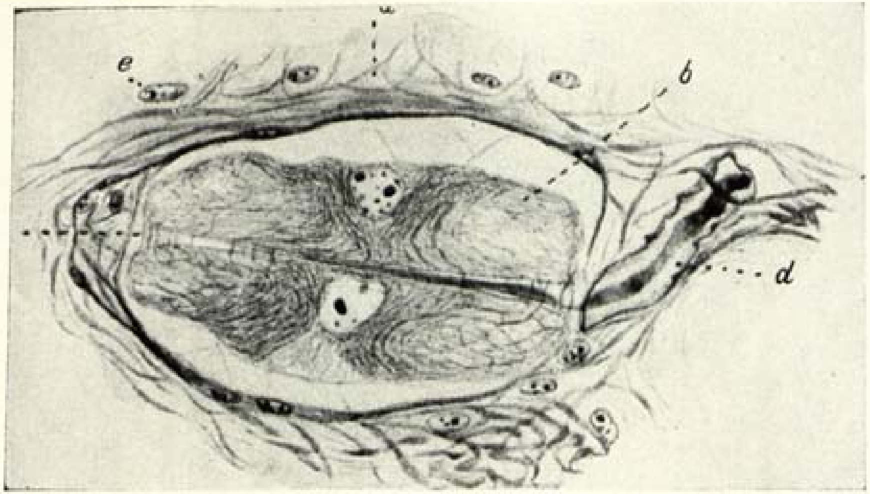
OPHTHALMOSCOPIC APPEARANCE OF THE INNER ASPECT OF THE RETINA AS SEEN THROUGH THE PUPIL, SHOWING POSITION AND EXTENT OF AREA AND FOVEA

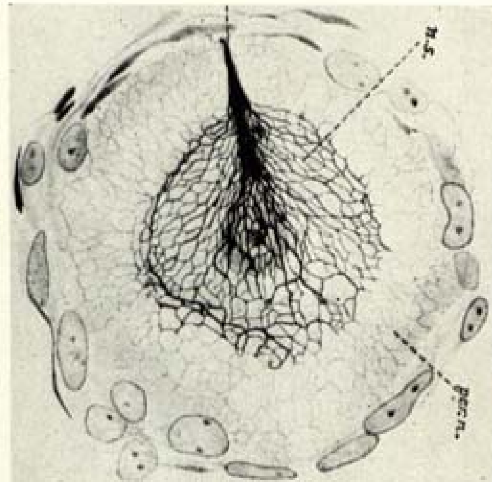
(After Wood 1917.)



RIGHT AND LEFT ASPECTS OF THE PLUCKED HEAD OF THE LONG-EARED OWL
ASIO OTUS

The operculum is turned outward and forward to expose the external meatus. *M. e.*, cavity terminated by tympanic membrane; *d*, blind cavity. (From Pycraft, 1898.)





TACTILE END ORGANS IN BIRDS

1. Section of a Grandry corpuscle from the bill of a duck, showing the unmedullated termination of the axon, *d*, entering between the capsule cells ,*b*.

2. Section of Grandry corpuscle at right angles to the plane of figure 1, showing the terminal network of the nerve fiber.

Insect Control Investigations of the Orlando, Fla., Laboratory During World War II

By E. F. Knipling, *Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture*

[With 6 Plates]

Early in 1942 the Bureau of Entomology and Plant Quarantine in the United States Department of Agriculture reviewed its research projects for the purpose of realigning them in closer correlation with the exigencies of war. Inasmuch as funds are usually appropriated for specific purposes, it is difficult to make sudden shifts from one project to another. This difficulty was considerably alleviated, however, by funds provided by the Office of Scientific Research and Development of the National Emergency Council. This transfer of funds was prompted by requests for research on medical entomology by the Surgeon General's Office of the United States Army.

This paper is designed to review briefly the conspicuous accomplishments of the men and women who participated in the research conducted at the Orlando laboratory during the period from March 1942 to October 1945. During this period much information on the control of insects, especially those carrying disease, was developed and was applied under emergency conditions by our military forces. The practical use of this information was a notable contribution to the successful termination of the war. The first recommendations on the use of DDT and other insecticides for controlling body lice, vectors of typhus, mosquitoes, vectors of malaria, dengue filariasis, and encephalitis, and yellow fever were made by the Orlando personnel. The number of persons involved, including the technical personnel, clerical staff, and human guinea pigs, averaged less than the number of one company of infantry; yet, the recommendations made by these workers, no doubt, saved thousands of lives and prevented the loss of hundreds of thousands of man-days which otherwise would have been caused by insect-borne diseases.

The total funds expended amounted to less than the cost of one of the smallest cargo vessels, yet the findings of this group of researchers now form the basis for our present methods of controlling some of the most devastating and debilitating diseases of mankind.

For centuries man has been in continuous conflict with dangerous and treacherous insects. Insects and their allies (ticks and mites will be called insects in this paper) directly and indirectly have taken a tremendous toll of human lives, but until the advent of DDT we had no very effective method for stopping an onrushing epidemic of typhus. Neither had we an effective method for killing adult and larval mosquitoes with one application of an insecticide. Today, however, a widespread epidemic of malaria can be stopped within a matter of hours by the

comparatively simple expedient of applying 2 quarts of a 5-percent DDT solution per acre from an airplane. Flies, potential transmitters of dysenteries, typhoid, cholera, and other diseases can be brought under control by the judicious use of recommended procedures first initiated by members of the Orlando laboratory.

Although these new insecticidal formulations were designed for military needs they can be revised, modified, and used for the benefit of a world at peace. During the past 5 years, entomologists and others from around the world have paid their respects to the Orlando laboratory and have returned to their native lands with information which is being applied to their peculiar insect problems.

Organization of the Orlando Laboratory and Its Relationship to Other Research Institutions

Fortunately the urgent need for modern and effective methods for controlling insects of medical importance was known by at least a few farsighted entomologists and medical officers. To Col. W. S. Stone and Gen. J. S. Simmons, United States Army, however, goes the greatest credit for initiating research programs especially designed to furnish the much needed information. Together with colleagues in the War and Navy Departments these men sitting in selected committees in the National Research Council first contacted the Bureau of Entomology and Plant Quarantine late in the fall of 1941. Plans for research projects designed to protect the health of our military personnel from insect attack and insect-borne diseases were shortly outlined by F. C. Bishopp, E. C. Cushing, and H. H. Stage of the Bureau and submitted to the Committee on Medical Research of the Office of Scientific Research and Development where they received favorable consideration. The first funds were allocated by the Office of Scientific Research and Development to the Bureau early in 1942.

Within a few weeks selected entomologists, insecticide chemists, engineers, and others were transferred to Orlando and charged with the responsibility of initiating the prescribed investigations without delay. R. C. Bushland, C. C. Deonier, G. W. Eddy, Howard A. Jones, A. W. Lindquist, A. H. Madden, L. C. McAlister, H. O. Schroeder, and B. V. Travis working under the immediate direction of W. E. Dove, and later, of the writer, formed the nucleus of this organization. As the program progressed, additional specialists were added to the staff. These included James B. Gahan, C. N. Husman, J. P. Linduska, O. M. Longcoy, F. M. Snyder, F. A. Morton, and others, including valuable and capable young men assigned to the laboratory by the Army Air Forces base at Orlando and by the Office of the Surgeon General, U. S. Army. The separate contributions of these men cannot be given here. They worked as a team, and because of their close cooperation and coordination of work their accomplishments were far greater than would have been possible if working as independent researchers.

The laboratory as a whole functioned as an important cog in the machine which produced the many new developments in insect control during the war. Industry furnished most of the chemicals which were evaluated as insecticides. These were tested against a number of insects and those that were worthy of practical consideration were developed through intensive study to a point where the armed services and other insect control agencies could try them out under practical conditions and develop them further for use in actual control operations.

As the research program developed and as reports from war theaters emphasized the importance of insects and insect-borne diseases to our war effort, various agencies set up research proj-

ects or expanded available facilities to undertake research along lines underway at Orlando. The Orlando group cooperated with these agencies which included the U. S. Army and Navy, Rockefeller Foundation, Tennessee Valley Authority, Food and Drug Administration, U. S. Public Health Service, and various groups conducting research under contract with the Office of Scientific Research and Development. Close contact and exchange of information was also maintained with laboratories and scientific workers in allied foreign countries.

Financing

The approximate expenditure of funds allotted the Bureau by the Office of Scientific Research and Development during the period March 1942 to October 1945 totaled $815,000. In addition the Bureau furnished available facilities such as automatic equipment, experimental aircraft, laboratory facilities, equipment and administrative supervision. The Army also contributed much in the way of equipment, especially experimental aircraft, as well as enlisted personnel, and aided in many other ways. In general the over-all expenditure of funds to carry out the research program during the war at the Orlando laboratory amounted to about 1 million dollars.

Problems Studied and Results Obtained

To appreciate fully the scope of the research undertakings at Orlando, the reader should bear in mind that many kinds of insects were involved in our global attack on the problem and that control measures had to be applied under many conditions throughout the world.

The objective of the laboratory was to appraise quickly and in a simple way the potential value of materials and methods under consideration for insect control. During the course of the investigations approximately 10,000 chemicals, chemical formulations, or items of equipment were studied. Our main job was to sift the wheat from the chaff, so to speak, and of this number hardly more than one dozen reached a state of practical use. The development of a material for practical application with a minimum of delay was uppermost in the minds of the research personnel. There was little time for methodical research—many important leads which a peacetime or an academic scientist might wish to follow were discarded. Instead, we cut corners whenever possible in order to reach an end point to make specific recommendations or to suggest what might be tried by the army in large-scale practical tests. We had to keep in touch with industry, for industrial firms assumed the responsibility of manufacturing or formulating the products and only materials which could be produced commercially were investigated extensively. It was necessary to consult with toxicologists who assumed the responsibility of judging if materials were safe to use on man.

Because of the necessity of this practical approach to the problems under study there was little opportunity for basic work. However, basic research was undertaken when necessary, and in the course of investigations much information of a fundamental nature was developed.

The major projects undertaken and the results accomplished are briefly discussed in the pages that follow. Although the major objectives were clear-cut, the course of the work and the degree of emphasis on various aspects were shifted as the research progressed and as the needs of our military forces and others faced with the problem of protecting themselves from insect attack were presented.

Lice

The project given the highest priority during the early stages of investigation was the control of human lice. Of the three species attacking man (body louse, head louse, and crab louse), the body louse (*Pediculus humanus corporis*, Deg.) was of most

concern to the military because of its role as the vector of typhus. The research was, therefore, centered around this species, and only the more effective materials were tested against the other two forms with necessary adaptations when this seemed desirable.

In carrying out louse control studies, the usual system of testing promising materials against natural insect infestations was not practical because body louse infestations are scarce in this country. The entire research program was accordingly planned so as to develop treatments under laboratory or simulated practical conditions. To do this we needed an unlimited supply of lice with which to test chemicals in the laboratory. The final field tests under conditions of practical use were undertaken by the armed services and by such agencies as the Rockefeller Foundation.

Because of our method of attack in carrying out the research on louse control, it is apparent that the maintenance of a louse colony was among the most important aspects of the louse program. G. H. Culpepper maintained the colony for over 3 years. As many as 25,000 to 75,000 lice in all stages of development and an even greater number of eggs were available at all times. The lice required their blood meals at regular intervals, and human subjects provided these meals, which were offered twice each day. We owe much to these men who served as subjects, for giving a blood meal to as many as 50,000 lice at one time is not a pleasant task. Fortunately each subject had a rest of about 2 weeks between feedings, but the same men served as human guinea pigs for other phases of the louse work and other projects which will be described later. Plate 1, figure 1, shows the method employed in feeding the lice. Between 2 to 3 percent of the subjects reacted so severely that they were unsuitable as hosts. In between meals the lice were held at a temperature of 86° F. and at a relative humidity of about 60 percent.

Methods for testing various insecticides as potential louse killers had to be developed. R. C. Bushland, G. W. Eddy, H. A. Jones, N. B. Carson, who were responsible for the laboratory phases of the louse project, considered and tried various procedures which permitted accurate and reliable methods of determining if a given material was worth testing on lousy individuals.

The first procedures consisted of a simple test in which lice were exposed on chemically treated cloth placed in a small beaker. Some 7,500 chemicals were tested in this manner. Only a few were worth testing by the second method, known as the arm-and-leg method. The cloths shown on the arms and legs of subjects (pl. 1, fig. 2) were treated with test chemicals, and lice were confined in them for at least 1 day. The lice did not suffer from lack of nourishment, as any of the subjects wearing ineffective treatments would testify.

The third step which was carried out under the supervision of L. C. McAlister and G. H. Culpepper required the full cooperation and extreme patience of our research subjects. In this test, the subjects lived in barracks and were dressed as our soldiers would be. They wore part woolen winter underwear. Several hundred lice and a thousand or more eggs from the colony in various stages of development were then placed on each subject. Promising materials were then applied to the underwear as a 5-percent powder at the rate of 1 ounce per garment.

This was a rigid test and we felt certain that any material that would free our subjects of lice and keep them free of lice which were added at intervals of several days would be effective against natural infestations. The success of the materials in actual practice which we recommended to the armed services confirmed this belief.

The outstanding accomplishments

in connection with the louse control investigations were the development of the MYL louse powder and the subsequent research on DDT which lead to the adoption and widespread use of this now well-known insecticide by the armed services and by civilians for the control of lice.

MYL powder.—The research on various insecticides as louse killers actually started late in April 1942. During the first 6 months several hundred materials were tested against lice and their eggs. Some of the many synthetic organic compounds tested were found to be highly effective against lice, but a day or two after treatment the subject would get lousy again. This lack of lasting effect was the major objection to fumigants such as methyl bromide which had been developed as a louse fumigant earlier by Randall Latta of the Bureau of Entomology and Plant Quarantine. Others were not suitable because they were too toxic to man, because they had an unpleasant odor, or because they stained clothing.

Pyrethrum and rotenone, two widely used insect killers, had previously been employed for louse control and were considered relatively nontoxic to man. Extensive tests indicated that these materials were fairly good louse killers provided they were properly formulated. However, rotenone was eventually discarded because of skin irritation and its extremely slow action. Pyrethrum was the most promising but supplies were very limited. In efforts to extend its use various materials known as synergists, which were employed in pyrethrum fly sprays, were tested. One of these, N-isobutylundecylenamide, was shown to be outstanding. When used in combination with pyrethrum it increased the action of the insecticide many times even though alone it would not kill lice. While research on louse-killing agents was underway, various tests were also in progress on materials that would kill louse eggs. As a result of these various studies a louse powder was formulated which contained 0.2 percent pyrethrins (principal toxicant); 2 percent N-isobutylundecylenamide (synergist); 2 percent 2,4-dinitroanisole (ovicide and added louse toxicant); 0.25 percent phenol S (a mixture of isopropyl cresols which stabilize the pyrethrins); and pyrophyllite (diluent).

This preparation, designated the MYL formula, was recommended to the armed services in August 1942. The powder was the most effective material known for use on man for control of body lice, head lice, crab lice, and fleas. It served a useful purpose and was the standard insecticide powder until DDT was developed and became generally available.

DDT louse powder.—Available pyrethrum was urgently needed for mosquito control, and research on new materials continued in the effort to find a synthetic compound for louse control which would be equal to, or more effective than, the MYL powder. Within a few months almost a thousand chemicals were tested, and several samples of other materials were being received from various sources each day. Tests were underway with several chemicals which showed considerable promise, but they were not the answer to our problem.

In November 1942 a prepared insecticide called "Gesarol Dust Insecticide" was received from the J. R. Geigy Co. of New York, a subsidiary of the Geigy firm in Switzerland, where it was developed through the important research of Paul Mueller and his associates. A sample of the insecticide was obtained through the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine. This prepared insecticide contained as the active principle the material now known as DDT, although when we first received it we knew little about its chemical composition. Tests soon demonstrated that this material had insecticidal properties possessed by no other synthetic organic compound known at that time. The material showed a

high degree of toxicity to lice, and the toxic action persisted for an unusually long time.

Tests were made with various concentrations of the product, using many types of preparations. A 10-percent DDT powder was shown to kill all lice on an infested subject and provide protection against reinfestation for at least 3 weeks. This was the type of material we were looking for.[1] Our chief worry was: Can the chemical be used safely on man? The Food and Drug Administration was attempting to determine the answer to this question. After several months of intensive study they concluded that in dust form DDT was entirely safe to use. By May 1943 DDT was recommended to the armed services as a safe and effective louse powder.

The success of DDT in controlling lice and typhus, as demonstrated by scientists in the North African War Theater, the U. S. A. Typhus Commission and the Rockefeller Foundation, is a story in itself that should be told by those agencies mentioned. It will suffice to say that we had more than gained our major objective. We now believe that DDT provides the means of not only controlling lice and typhus but of eventually eradicating typhus from the earth.

Other developments.—The work on louse powders represented the most important developments in connection with the louse program. However, many other significant contributions were made and the two most outstanding are listed below:

1. It was found that DDT was far more effective and persistent when impregnated in clothing than when employed as powders. When impregnated in the underwear at suitable concentrations the DDT continues to kill body lice for as long as 6 months provided the clothing is not washed. If laundered according to usual procedures, the clothing remains effective even after 4 to 8 washes.

2. A liquid preparation known as the NBIN formula was developed for the control of lice, especially head lice. This was prepared as a concentrate which when diluted with 5 parts of water contained approximately 1 percent of DDT, 2 percent of ethyl p-amino benzoate (benzocaine), 11 percent of benzyl benzoate and 2 percent of an emulsifier known as a poly oxyethylene derivative of sorbitan monooleate.

Mosquitoes

More attention was given to various aspects of research on mosquito control than to any other project. This was justifiable because mosquitoes as a group are probably the most important insects in the field of medical entomology. Investigations on this problem concentrated along three major lines of research: (1) larvicides, (2) insecticides for adult mosquitoes, and (3) repellents.

There are hundreds of species of mosquitoes, which vary in their habits and resistance to insecticides and repellents. It was possible to carry out extensive studies on only a few representative species. For the laboratory aspects of the program two species were chosen, the malaria mosquito (*Anopheles quadrimaculatus*) and the yellow fever mosquito (*Aedes aegypti*). The rearing of large numbers of mosquitoes which were needed for research on larvicides, adult sprays, and repellents, was a major undertaking in connection with the research project. The *Anopheles* are not easily reared under laboratory conditions in large numbers, but as many as 50,000 mature larvae or adults were needed each day during the peak of the program. Plate 2, figure 1, shows one of the rearing rooms for the *Anopheles* colony.

[1] Swiss workers, as we learned after our studies were well advanced, had demonstrated the value of DDT as a louse insecticide, and the Geigy firm was producing a product for this purpose called Neocid which contained 5 percent DDT.

LARVICIDE INVESTIGATIONS

The project on mosquito larvicides, started in October 1942, was under the direction of C. C. Deonier, and during the 3-year program he was assisted for various periods of time by R. W. Burrell, C. B. Wisecup, J. D. Maple [2], and others. These men and their assistants tested many new chemicals (pl. 2, fig. 2) and tried to improve the efficiency of known mosquito larvicides such as paris green. Not much progress was indicated until early in February 1943, when DDT was tried for the first time.

Before DDT was tested, the best mosquito larvicide known was the chemical phenothiazine, which killed larvae of the common *Culex* mosquitoes at concentrations as low as 1 part per million parts of water. When DDT was given preliminary laboratory tests at various concentrations, it was found that complete or near complete kill of *Anopheles* larvae resulted at the extremely low concentration of 1 part of DDT to 100 million parts of water. A kill of approximately 50 percent was obtained at the then unheard of dilution of 1 part to 400 million. There was reason for real optimism; here was a material exactly 100 times as toxic to mosquito larvae as was phenothiazine, the most effective synthetic organic larvicide previously known.

The next problem was to compare the efficiency of DDT when employed as a dust in direct comparison with paris green, the standard anopheline larvicide. In the laboratory it was found that complete kill of *Anopheles* larvae was obtained at the very low rate of application of 1 pound of DDT to 100 acres of water surface. This was at least 25 times as good as paris green.

With this basic information the research on DDT was intensified. It was tested in every form in which it might be used—as dusts, oil solutions, emulsions, and aerosols. Studies were made at different dosages, and against the larvae of several kinds of mosquitoes. Because DDT cannot be applied in its natural form, DDT formulations employing various solvents, emulsifiers, and dust diluents, prepared by Howard A. Jones, our chemist, were investigated.

Tests were run in the laboratory, and small-scale field tests were made (pl. 3, fig. 1). The field tests confirmed the potential value of DDT as a mosquito larvicide: as little as 1 pound of DDT to 20 or even to 40 acres gave a good kill of *Anopheles* larvae. But to provide an ample margin of safety we recommend that in actual control operations (using ground equipment) it be applied at the rate of 1 pound to 10 acres. It was recommended to the armed services as a dust, in petroleum oil solution, and in special emulsion concentrates which could be diluted with water before application as a spray.

When used as an oil solution, it was found that 5 quarts of oil containing 1 percent of DDT, properly applied, would do as good a job of killing mosquito larvae as 20 to 25 gallons of oil when used without DDT. This was real progress, especially from a military viewpoint, because of the tremendous saving in transportation.

For military purposes, however, the emulsion was one of the most practical forms of DDT to use, chiefly because of further savings in transportation costs. One-half pint of a 20-percent DDT emulsion concentrate could be diluted with water from the mosquito breeding area and applied with results equal to those formerly obtained with the 20 to 25 gallons of oil previously mentioned.

The use of DDT as a mosquito larvicide is by no means restricted to ground equipment, and special research was undertaken to develop it

[2] J. D. Maple entered the U. S. Navy as lieutenant (jg) early in 1944 and was attached to Naval Medical Research Unit No. 2, which was detailed to the Pacific to conduct further research with materials developed at Orlando. He lost his life while on active duty in connection with this assignment.

for application by means of aircraft. Largely owing to developments by the Bureau of Entomology and Plant Quarantine and the Tennessee Valley Authority, airplanes had been used extensively in connection with the control of insects attacking agricultural crops and anopheline larvae. In the first efforts to apply DDT from the air, dusts were employed. In collaboration with TVA scientists it was shown that DDT applied in this way was effective, but the physical properties of dusts containing a high percentage of DDT were such that they were difficult to apply with existing equipment. Efforts to apply DDT from the air were accordingly concentrated on the development of sprays. C. N. Husman, engineer, and O. M. Longcoy, pilot, developed experimental models of aerial sprayers which would deliver and distribute about 2 quarts per acre of sprays having rather small droplets. All early experimental work was done with a Piper Cub plane (L–4) equipped with sprayers (pl. 3, fig. 2).

Field tests on natural breeding areas with such equipment, after experimental tests on larvae in ice cream cups, demonstrated that good control of larvae resulted with a 5-percent DDT oil solution or emulsion applied at the rate of 1 to 2 quarts per acre.

Since little was known about the application of liquid insecticides from airplanes, the experimental work on the development of DDT larvicide sprays involved studies with various types of equipment, relation of particle size to effectiveness of the spray, relative effectiveness of different formulations, optimum concentrations of DDT in the spray, and many other factors. The potentialities of the utilization of aircraft for dispersing DDT sprays was called to the attention of the Army Air Forces Board of Orlando, Fla., and as early as December 1943 cooperative tests were undertaken utilizing fast combat planes equipped with standard Chemical Warfare Service devices. Studies on many aspects of the aerial dispersal problem continued during 1944 and 1945, and a number of other agencies undertook investigations during that period including several branches of the Army, both at home and overseas; Tennessee Valley Authority; U. S. Navy; National Defense Research Committee; and others. Consequently, by 1945, planes ranging in size from L–4's to C–47 transports were equipped with improved aerial spray equipment, and the armed services were prepared to blanket DDT over mosquito breeding areas involving, if necessary, thousands of acres.

KILLING OF ADULT MOSQUITOES

The complete story of the important research on DDT for controlling adult mosquitoes, if related in detail, would require more space than is allowed for the entire topic under discussion; therefore, only the high spots of this subject will be reviewed. The investigations designed to improve on materials and methods to kill adult mosquitoes involved research on aerosols and sprays and on residual treatments. The work on adults was under the supervision of A. W. Lindquist, and his assistants included J. B. Gahan, H. O. Schroder, A. H. Madden, H. G. Wilson and others. B. V. Travis and F. A. Morton who were investigating repellents also took an active part in the early studies on the control of adult mosquitoes. The many chemical aspects involved in these investigations were under the supervision of Howard A. Jones, who was assisted by Miss Helen Fluno, Corp. C. T. McCollough, and others.

Aerosols and sprays for use indoors.—As early as 1942 the armed services were already employing the famous aerosol bomb for the control of flies and mosquitoes. This unique principal of dispersing aerosols was developed by L. D. Goodhue and William Sullivan of the Bureau of Entomology and Plant Quarantine. The problem at Orlando was to explore the possibility of utilizing DDT in the aerosol for-

mula in order to improve its insecticidal action and to conserve pyrethrum, and this was done in cooperation with other researchers in the Bureau. It was soon shown that DDT had effective killing power against mosquitoes and especially against flies but lacked the rapid knock-down properties that pyrethrum possessed. Many tests were conducted with various concentrations of DDT and pyrethrum in order to obtain the proper ratio of these insecticides. Various solvents and other auxiliary materials were employed in testing different formulations. The outcome was a liquefied gas aerosol formula developed in cooperation with L. D. Goodhue, E. R. McGovran, and others of the Beltsville Research Center, which contained 3 percent of DDT, 0.4 percent of pyrethrins, 5 percent of motor oil, and 5 percent of cyclohexenone. The U. S. Public Health Service conducted toxicological tests with this formula and judged it safe for use.

As the research on aerosols was in progress, efforts were also directed toward the development of highly concentrated sprays. It was shown that within wide limits the amount of insecticide dispersed governed the kill of flies or mosquitoes regardless of the amount of liquid carrier actually atomized. For example 1 cc. of a 20-percent DDT solution finely atomized in a given space was as good as 20 cc. of a 1-percent solution applied in the same manner. The same principle held with pyrethrins. As a result of these studies, sprayers smaller than a flashlight were developed, which contained the insecticide equivalent to about 2 gallons of ordinary household-type pyrethrum sprays. Although such devices and spray formulas were not utilized during the war, primarily because the aerosol bomb had been supplied and distributed in adequate numbers, the investigations definitely established the potentialities of highly concentrated solutions for use as sprays.

Residual treatment.—The greatest single advance in the control of insects of medical importance was the development of the residual or surface treatment concept of mosquito and mosquito-borne disease control. Even before DDT became available, the principle of controlling insects by means of surface treatments utilizing pyrethrins and other toxicants was under investigation at the Orlando laboratory. The high degree of toxicity and stability of DDT seemed to offer promise for this method of insect control; consequently when this insecticide was available it was tried with preliminary indications of success. Studies were therefore intensified on this problem. It was not known at the time that R. Weisman of Switzerland had already demonstrated the possibilities of DDT as a residual treatment in controlling insects through his highly significant work on flies. The Orlando laboratory independently developed DDT for fly control and proved its value for controlling mosquitoes and certain other insects.

Since the residual or surface treatment method of controlling mosquitoes as well as other insects was new, many aspects needed investigation. Various kinds of surfaces were treated with DDT using different amounts and different kinds of preparations. Mosquitoes were confined for specified periods of time in specially constructed cages treated with the DDT (pl. 4, fig. 1). Tests demonstrated that the killing action lasted for weeks, then months. Finally, after about 8 months the laboratory tests were discontinued even though the better treatments were still killing adult mosquitoes.

While the laboratory tests were still in progress, the principle of residual treatments was tried in actual field tests (pl. 4, fig. 2). In 1943 several types of buildings were sprayed with DDT. By the end of the mosquito season, as long as 70 days after the first treatments were applied, *Anopheles* mosquitoes entering the build-

ings were still being killed. Special tests were made which demonstrated that the mosquitoes readily entered the treated buildings, and by the time they were affected by resting on treated surfaces and began leaving, they had accumulated a fatal dose of DDT. This was a vital point and practically assured the success of the method as a means of breaking the link in the chain of malaria transmission even though malaria control had not yet been demonstrated. On the basis of these observations together with those from residual tests against house flies, bed bugs, and other insects, which indicated that the insecticide remained effective for several months, the DDT residual treatment for malarial control was recommended to the armed services.

More extensive tests were undertaken in 1944 and 1945 in the vicinity of Stuttgart, Ark., and in Mexico. These tests yielded highly important information and fully confirmed our earlier tests. The tests in Arkansas in 1944 were undertaken in cooperation with the Arkansas State Board of Health. The treated buildings were almost completely free of *Anopheles* adults for 5 months, or the entire mosquito season. Tests in Mexico in 1945 in cooperation with the Rockefeller Foundation gave similar results.

The Army, Navy, Public Health Service, and other agencies carried out further investigations in 1944 and 1945 with this method of mosquito control in various parts of the world against several species of *Anopheles* mosquitoes. Results everywhere were phenomenal.

At present, DDT residual treatments are widely employed, and this method alone has potentialities of freeing mankind almost everywhere from malaria and other mosquito-borne diseases—diseases which according to medical authorities afflict more than 100 million people throughout the world and cause several million deaths each year.

Area control of mosquitoes.—Larvicides, aerosols, and residual sprays will not take care of the adult mosquitoes that have dispersed from breeding places and which are living in extensive areas outdoors. In order to provide methods of attack against mosquitoes under every type of situation, research on the destruction of mosquitoes under these conditions was undertaken as a part of our broad attack on the entire mosquito problem. Studies were initiated using hand sprayers, dusters, small smoke machines, and aerosol bombs. It was shown that DDT applied outdoors would eliminate mosquitoes present even in heavy jungles. Hand equipment had its place in protecting troops from mosquito attack, but the method was not feasible for large areas because of the labor involved.

In efforts to control mosquitoes over extensive areas two methods of approach were investigated. These were aerial dispersion and the utilization of ground machines that would generate aerosols in sufficient volume to be carried by air currents over large areas. The airplane equipment developed for larval control has already been discussed and the same equipment was also developed for utilization against adult mosquitoes. The early work on devices to generate aerosols by use of heat was largely undertaken by Division 10 of the National Defense Research Committee in cooperation with the Beltsville Research Center.

Small-scale field trials in the fall of 1943 with experimental models of airplane insecticide dispersal equipment demonstrated that salt-marsh mosquitoes could be controlled at dosages as low as 0.2 pound of DDT per acre. Results of these tests together with the results of larval control research were recognized as highly important by the Army Air Forces and by the Office of the Surgeon General, U. S. Army. The former sponsored tests with DDT utilizing the Chemical Warfare Service M-10 tanks on fast combat planes, and it was shown

that control of adult mosquitoes was possible through the use of this equipment.

The crucial tests on adult mosquito control on an area basis employing airplanes were conducted in Panama. The Office of the Surgeon General, U. S. Army, arranged for such tests against tropical *Anopheles* and other mosquitoes. In March of 1944 Mr. Lindquist and Mr. Husman of the Orlando staff were issued Army orders to proceed to Panama with equipment and materials. The tests were made in cooperation with Army personnel in Panama. If tropical *Anopheles* could be controlled in jungle areas with DDT sprays applied from the air, the Army would try the method on a large scale against other species in various parts of the world.

Two tests were made on 50-acre plots, each using the Husman-Longcoy spray unit on an L–4 plane already mentioned (pl. 3, fig. 2). The results were phenomenal. A reduction of at least 95 percent of adult *Anopheles* and other mosquitoes was indicated, and complete control of larvae was obtained when breeding areas were present in the area sprayed. For at least a week the population of the mosquitoes in the treated area was greatly reduced. Thus the effectiveness and feasibility of adult mosquito control on an area basis were established.

I shall not attempt to review further developments except to state that improved spray equipment consisting of spray booms placed under the wings of the aircraft were developed for use on L–4 and PT–17 planes. Preliminary studies were also undertaken with smokes and aerosols dispensed through the exhaust pipe of aircraft. Other agencies made important contributions in developing aerosol spraying for mosquito control. The Tennessee Valley Authority and Division 10 of the National Defense Research Committee concentrated on and developed the exhaust type of equipment which is now widely employed; the Army Air Forces developed spray equipment for B–25 bombers and C–47 transports; and the Navy, in cooperation with the Orlando personnel, developed spray equipment for the TBM and TBF airplanes (pl. 5, fig. 1). Overseas units in the Army and Navy independently constructed equipment for aerial dispersion of DDT.

No phase of the insect-control work created greater or more widespread interest than did the aerial spray program for destruction of mosquito larvae and adults. Special missions organized by the Army and Navy were sent to different areas to conduct practical field tests with various kinds of equipment. One such mission in Panama was discussed by my colleague, H. H. Stage, in an article in the 1947 Smithsonian Report.

Aerial dispersion provided an effective means of quickly bringing under control the mosquitoes already present in infested areas. The destruction of the adults in 24 hours or less, including any that might be infected with diseases, eliminated overnight the possibilities of disease transmission. Control of larvae at the same time meant that in large areas at least 3 weeks of protection from mosquito disease transmission was assured.

The Army and Navy in 1945 actually treated entire islands in the Pacific and extensive areas in other war theaters for the control of mosquitoes and flies. At present, civilians are treating large areas for control of adult mosquitoes and other related insects. The research on dispersion of aerosols from the ground also went forward, sponsored by Division 10 of the National Defense Research Committee and other agencies. Such devices, greatly improved, are now included among the weapons for eliminating various insects attacking man. Five years ago very few biologists could have visualized the future development of such methods of controlling the insect pests and disease carriers in dense tropical jungles or on the open tundra of the far North.

INSECT REPELLENTS

The major objective in insect control should be to destroy the insects themselves, but from practical considerations this is not always feasible. This is especially true in time of war when persons subject to attack are frequently on the move or are living without adequate means of protection from insects. When the research programs were initiated we did not have the several improved methods currently available for controlling mosquitoes and other related insects. The need for a good insect repellent was therefore considered urgent when work began, and intensive research was conducted on this project from 1942 to 1945. Even today with our improved materials and weapons for destroying mosquitoes and similar parasites of man, it may not be economically feasible to undertake control measures in some locations, especially in sparsely populated areas.

In carrying out the repellent program, several thousand chemicals were tested to determine their value as mosquito repellents when applied to the skin or to clothing. This project was under the supervision of Dr. B. V. Travis until April 1944, when he joined the Navy to conduct research on all aspects of insect control probems in the Pacific. F. A. Morton assumed charge of the project during Dr. Travis' absence. These men were assisted by several able workers for varying periods of time, including J. P. Linduska, A. L. Smith, J. H. Cochran, and J. H. Robinson. Working with the scientists were from 8 to 20 research subjects, who day after day permitted their arms or other parts of the body to be exposed to thousands of hungry mosquitoes. This was not an unpleasant job when the materials under test were good and repelled the mosquitoes for several hours, but a high percentage of the compounds were either worthless or were of a low order of effectiveness.

For several years before the war, Phillip Granett of Rutgers University, working on a fellowship sponsored by the Carbide and Carbon Chemical Co., had been searching for repellents for mosquitoes, flies, and other insects. Using mosquitoes reared in the laboratory, over a period of several years, he had treated his arms with hundreds of chemicals and exposed them to mosquitoes in cages. Similar procedures were followed in conducting the tests at Orlando, but the research was on a more elaborate scale.

In the search for repellents, arms of the subject treated with the test material were inserted into cages containing from 2,000 to 3,000 hungry mosquitoes (pl. 5, fig. 2). If the mosquitoes soon ignored the treatment and proceeded to bite, the chemical was discarded. If, however, no bites were received during a period of 3 hours the material was considered worthy of further study in the laboratory and in the field. For field tests, as shown in plate 6, figure 1, the repellent crew usually visited the salt marshes along the east coast of Florida. Tests were not conducted unless as many as 20 mosquitoes landed on the exposed portion of a leg, from ankle to knee, in 1 minute. On some occasions as many as 100 mosquitoes landed on an untreated leg in 1 minute.

The first objective of the repellent program was to evaluate thoroughly all materials known or reported to possess repellent properties so that the best ones that were safe to use could be employed by the armed services. Within 6 months after the research was started three materials, found by industry to be good insect repellents, were tested under various conditions and then recommended to the military forces as repellents. These were dimethyl phthalate, Rutgers 612 (2-ethyl-1,3-hexanediol) and Indalone.

All these chemicals are good insect repellents. They could be expected to give an average of about 2 hours of protection against the yellow fever and salt-marsh mosquitoes. The length of protection varied,

however, depending on the individual, the condition of the skin—whether dry or wet from perspiration—the number and species of mosquitoes, and other factors.

To overcome some of the variations, it was decided to mix all three of the repellents that had been recommended to the armed services. Tests against several kinds of mosquitoes under various conditions indicated that a mixture of the repellents was more uniformly effective against a variety of insects than any one of the three alone. In some cases the mixture was actually better than each of the three individual repellents. On the basis of these studies a 6–2–2 combination (60 parts of dimethyl phthalate and 20 parts each of the other two repellents) was adopted by the services as the standard repellent. The repellents were primarily for application to the skin but they also served a useful purpose when applied to clothing so as to keep mosquitoes from biting through.

During 1944 and 1945 work on repellents was intensified by the Orlando laboratory as well as by other agencies in efforts to find more effective and more desirable materials. The goal was a preparation, cosmetically acceptable, that could be applied with assurance that the user would be protected from attack for about 10 hours, or at least overnight. The Office of Scientific Research and Development arranged research contracts with several universities to synthesize or furnish new materials, especially chemicals related to known repellents.

As a result of the intensified program several thousand new materials were tested and hundreds of creams and lotions were prepared and evaluated. I cannot review here all the work done during this period at the Orlando laboratory and by research groups with the armed services, universities, and in industry. Much worth-while information was obtained, the value of which may not be fully apparent for years to come. A number of very promising repellents were found. Some of them are now in use, and others are still being studied. However, in brief it may be said that we did not gain our objective. None of the new chemicals which were considered entirely safe to use were sufficiently effective to warrant their recommendation as replacements for, or to supplement, the three repellents and the 6–2–2 combination mentioned earlier. When the war ended, the repellents recommended in 1942 and 1943 were still in use by the services. Although far from perfect, they are distinctly superior to any repellents known prior to the war, when citronella and certain other essential oils were the only materials widely employed.

Flies

Flies of various kinds have always constituted a serious insect problem, not only because they are a source of annoyance, but because they spread filth and diseases. Some medical officers in the services considered flies as important as mosquitoes. Research on improved methods of controlling flies paralleled that of mosquitoes to a considerable extent.

After extensive laboratory studies, the first practical tests, utilizing DDT as a residual treatment, were conducted by treating dairies in the vicinity of Orlando. House flies have always been numerous in this type of environment even though the owner might have employed rigid sanitation and other control measures. In May 1943 fly counts were made around two dairies. One was treated with 5-percent DDT in kerosene; the other served as a control. Before treatment approximately 1,500 flies were collected around each dairy by making 15 sweeps with an insect net in places where flies concentrated. Within 24 hours after treatment the fly population around the treated dairy dropped by at least 95 percent. A week later the population was still less than 5

percent of the pretreatment level, whereas the fly counts remained unchanged around the untreated dairy. The same degree of control was maintained week after week until in October, when the fly season had practically ended, observations were discontinued. Similar results were obtained around other dairies. Thus a single thorough treatment with DDT caused immediate reduction in fly populations of over 95 percent under the most difficult of circumstances, and this degree of control persisted for the entire season. If similar results could be obtained around military installations, one of the most serious military problems could be largely solved.

The Orlando Air Base and the Fourth Service Command Corps of Engineers headquarters at Atlanta, Ga., cooperated in conducting similar tests in military installations. Spectacular results were also obtained under these conditions. On the strength of these studies, together with the elaborate studies which were still underway in the laboratory against both flies and mosquitoes, the potentialities of DDT residue treatments for fly control was called to the attention of Army and Navy Personnel and Public Health Service workers. In 1944 the Army and Navy began employing DDT for fly control in many parts of the world, and almost everywhere reports indicated excellent results.

This means much to us in the United States, but even more to the people of places in the world where a high percentage of the population might die as a result of fly-borne diseases. DDT or some similar insecticide used as a residual treatment can help solve sanitation and health problems everywhere.

Mites (Chiggers)

Most of us at one time or another have experienced the discomfort caused by one of our smallest arthropod parasites—the larval stage of mites, commonly called chiggers or red bugs. Fortunately, in the Americas our chief concern with this pest is the irritation caused by the bite. This alone, however, was sufficient reason to undertake intensive research to develop more effective methods of control. In the fall of 1942 medical officers participating in Army maneuvers in Louisiana and certain other southern States reported a larger number of hospitalizations of military personnel due to infections resulting from chigger bites than for any other cause. Later, however, our armies in the Pacific and in the China-Burma-India theater experienced outbreaks of scrub typhus or Tsutsugamushi disease, transmitted by mites closely allied to the species found in this country. Although the disease was fairly well known before the war, its potential importance was not fully realized by our scientists and medical men. Fortunately, when serious outbreaks of mite typhus occurred among various military units in 1943 and 1944, we had already developed an effective means of protecting individuals from the vector.

When the mite typhus problem became acute in several war areas, the U. S. A. Typhus Commission undertook extensive investigations on the vectors of this disease and Australian scientists also concentrated on the mite problem. At the suggestion of the Typhus Commission our work on mites, carried out in close cooperation with that agency and the Office of the Surgeon General, was intensified. Capt. R. C. Bushland, formerly in charge of the laboratory phases of the louse project at Orlando, had entered the Army. He was attached to the Typhus Commission staff and assigned to the miticide aspects. As he developed the clothing impregnation method of mite control under field conditions using dimethyl phthalate, the work on new, more effective miticides was under way at Orlando by Fred M. Snyder, F. A. Morton, J. P. Linduska, Pvt. H. F. Cross, and others.

The objective was to develop a miticide which when impregnated in clothing would protect the individual even after the clothing was washed.

The Australians had found that clothing treated with dibutyl phthalate, chemically related to dimethyl phthalate, was effective even after it was laundered. DDT which had given us an effective weapon for so many of our other problems was of no value in controlling mites.

A. H. Madden and A. W. Lindquist undertook the early investigations on mites or chiggers. The objective was to develop a treatment which the individual could use to protect himself from mite attack. As with the louse and insect-repellent projects, human subjects acted as guinea pigs. These research subjects exposed themselves to chiggers in highly infested areas. Those wearing untreated clothing knew they were in for hours of irritation which the chiggers would cause. The others were only hopeful that the treatment applied to them would be a good one. Most tests were conducted in areas where untreated men could be expected to obtain up to 200 chigger attachments after a 2-hour exposure.

Many types of treatments were tested to protect individuals from chiggers, including insect repellents applied to the skin and dusts applied in clothing. The most significant advance in mite control, however, was the work on clothing treatment. When socks and army uniforms were treated with dimethyl phthalate or some of the other repellents and insecticides, and worn by subjects in heavily infested chigger areas, complete protection was obtained. This single treatment remained effective for several weeks. Good control was obtained also by spraying the repellents on the clothing. Even simpler methods were tried and it was found that excellent control could be obtained by applying a repellent barrier to the socks and all the openings of the clothing.

In evaluating the different miticides, definite steps were followed. Patches of cloth of the kind worn by service men were treated, and mites were placed on the treated cloth. If the mites were killed or immobilized within 15 minutes, the chemical was studied further to determine whether the treatment remained effective after the clothing was washed or laundered. Several thousand materials were evaluated in this manner (pl. 6, fig. 2), and the more promising of those which were not too toxic or possessed no objectional features were considered for practical tests. Samples of these were forwarded by the Typhus Commission to their men in the Pacific and to those in the China-Burma-India theater. The same materials were also tested further by the men at Orlando. The Chemical Warfare Service also investigated miticides and concentrated on binders such as chlorinated paraffins which might prolong the action of the mite treatments applied to clothing.

These studies produced a number of materials which were highly effective.

Benzyl benzoate was among the best that were know to be safe to use and that could be made available without much delay. Dibutyl phthalate was generally effective, but the degree of protection it afforded was somewhat erratic. Because of shortages of benzyl benzoate, the Office of the Quartermster Corps requested tests with a combination of this material and dibutyl phthalate and these tests indicated that a 50–50 mixture of the two miticides was approximately as good as benzyl benzoate alone. This mixture is now the Army's standard miticide. When the war ended, work was underway on a number of materials which, on the basis of preliminary tests, were even superior to benzyl benzoate.

Thus other important weapons were developed which protected our fighting forces from an enemy that experience with isolated units had indicated could be as destructive as the Japs.

Other Problems Investigated

Fleas.—Fleas, through the transmission of plague, have in the past

created much misery to peoples throughout the world. Even today plague rages in certain parts of the world and is of potential importance in the United States. Endemic typhus can be transmitted by fleas and is one of our common diseases. This insect was therefore also included among those investigated at the Orlando laboratory. Under the supervision of A. W. Lindquist, A. H. Madden, and others, we tried various repellents and insecticides. Although dimethyl phthalate and other mosquito repellents afforded some protection to individuals, a material which would kill fleas was more urgently needed.

When DDT proved so highly effective to a number of other insects, we naturally investigated this material for flea control. It was shown that fleas could be eliminated completely from infested areas by applying DDT sprays or dusts. Although slow in action, DDT was also useful for killing fleas on persons already infested or those subject to infestation. Its effectiveness as an all-purpose flea insecticide compared favorably with that as a louse killer or for mosquito and fly control.

Bedbugs.—Bedbugs have not been incriminated as disease carriers, but they are important from the standpoint of annoyance. In permanent military establishments, and of course among a high percentage of civilian homes and institutions, bedbugs constituted a major insect pest problem. Ordinary household type of sprays, heat, and fumigation were methods employed for controlling bedbugs. These treatments, however, were far from satisfactory.

The bedbug problem was undertaken in 1942 by A. W. Lindquist and A. H. Madden, the same men mentioned in connection with the research on mosquitoes, flies, mites, and other arthropods. Many insecticides were tested against bedbugs. Pyrethrum properly used and in sufficient amount was good, but we could not recommend that it be used because all available supplies were required for the disease-carrying insects.

When DDT became available, laboratory tests demonstrated that this insecticide when used as a residual spray remained effective for many weeks. Practical tests were then conducted in naturally infested homes. A thorough treatment of the walls, bedsteads, springs, and mattresses completely eradicated the bugs present. In order to determine how long the treatment would prevent reinfestations, 25 bugs from the laboratory colony were added to a bed in one of the treated homes at intervals of a week to a month. This test was continued for 16 months. Bedbugs failed to become established, and finally Mr. Madden gave up, even though bugs placed on the bed were still being killed after this period of time.

The next problem was to give DDT a thorough test under military conditions. The Orlando Air Base under the direction of Lt. Col. J. Q. A. Daniels carried out investigations along this line. A total of 6,000 beds and the quarters were treated, and during 6 months of checking no bedbugs were found. The Corps of Engineers obtained equally spectacular results in practical tests. We now say that DDT is the perfect answer to the bedbug problem for the military as well as for civilians.

Scabies investigations.—The human itch mite is widespread in distribution and is an important military problem. It is also important among civilians, especially among school children. The studies on itch mites, which were undertaken by G. W. Eddy, were greatly handicapped by a lack of sufficient cases for treatment. No method of colonizing this parasite is known. A treatment for scabies generally requires the application of materials to the entire body. It was necessary therefore to exercise extreme caution from a toxicological viewpoint in choosing materials for test purposes.

Even though the obstacles mentioned limited the amount of research that could be done on this problem, important progress was made.

Although several treatments were developed, the NBIN concentrate already mentioned in connection with the discussion on lice was adopted as the standard preparation. This material in concentrated form, when diluted (1 part in 5 parts of water) and thoroughly applied to the entire body, in all experimental cases gave complete control of scabies. There is strong evidence that this formula is more effective than other preparations containing the same amount of benzyl benzoate. This is thought to be due to added scabicidal and ovicidal properties of the benzocaine. There is no evidence that the DDT present aids in controlling scabies. Its function is to control lice when the preparation is employed for that purpose.

New materials were also tested to determine their scabicidal properties. In evaluating new compounds, it was necessary to limit the tests to a few selected materials. Only those that were toxicologically safe as determined by the United States Food and Drug Administration were considered. Even with these handicaps we discovered several chemicals which in preliminary tests were indicated to be equal to, or perhaps better than, benzyl benzoate.

Ticks.—These important disease transmitters were also included among the problems studied, but no important progress was made. Many materials considered to be effective insecticides or repellents proved useless against ticks.

Some measure of protection for individuals was provided by treating the clothing with dimethyl phthalate, benzyl benzoate, Indalone, and certain other chemicals. These treatments were considered to give 99 percent protection against the larval tick (seed ticks), 90 percent against the nymphs, and about 50 to 60 percent against the adult forms.

Culicoides (sand flies).—Culicoides and related insects are important in the United States chiefly as an annoyance. In certain regions of the world the true sand fly (*Phlebotomus*) is highly important as a disease carrier. No opportunities were afforded to test materials against *Phlebotomus*, but some repellent and insecticide tests were conducted against the *Culicoides* which are common and very annoying along the coastal regions of Florida. It was found that materials and methods useful for mosquito control were also helpful in combating the sand flies.

Educational Service

One of the most important functions of the Orlando Laboratory during its period of operation was to disseminate the information obtained on the control of insects of medical importance. Many people from various parts of the world visited the laboratory in order to get first-hand information on the most recent developments in the control of the insects under investigation. Most of these were entomologists, medical officers, and engineers in the armed services and in public health services who were charged with the responsibility of controlling insects and insect-borne diseases among military personnel and civilians. The visitors also included scientists from many of the Allied nations. Courses of instruction were offered to groups at regular intervals.

The constant stream of visitors naturally interrupted the research activities somewhat, but this educational service represented one of the most important functions of the laboratory. Information on new methods and materials to control insects was made available first hand to hundreds of men who in turn traveled to many parts of the world to instruct others on the use of new techniques for controlling insects. Others returned to their laboratories to carry out further research in efforts to improve on materials and methods already developed.

Members of the Orlando staff were

sent on special missions to various parts of the world by the Army and Navy for the purpose of disseminating the new information and to participate in important research activities designed to adapt control methods against important insects in their natural habitat.

Special reports under security restrictions were issued on all aspects of the research programs. These were made available for distribution by the Office of Scientific Research and Development to key personnel in the armed services and other institutions. Assistance was given to the Army and Navy in the preparation of training films which demonstrated how personnel in our services could protect themselves from attack by the many insects and insect-borne diseases.

Near the end of the war and immediately following, we undertook the task of publishing in technical form the vast amount of data accumulated in connection with the studies carried out over a period of almost 4 years. Many of the data may never appear in print, but the most significant contributions, contained in more than 150 technical papers, have already been published or are in the process of publication in scientific journals.

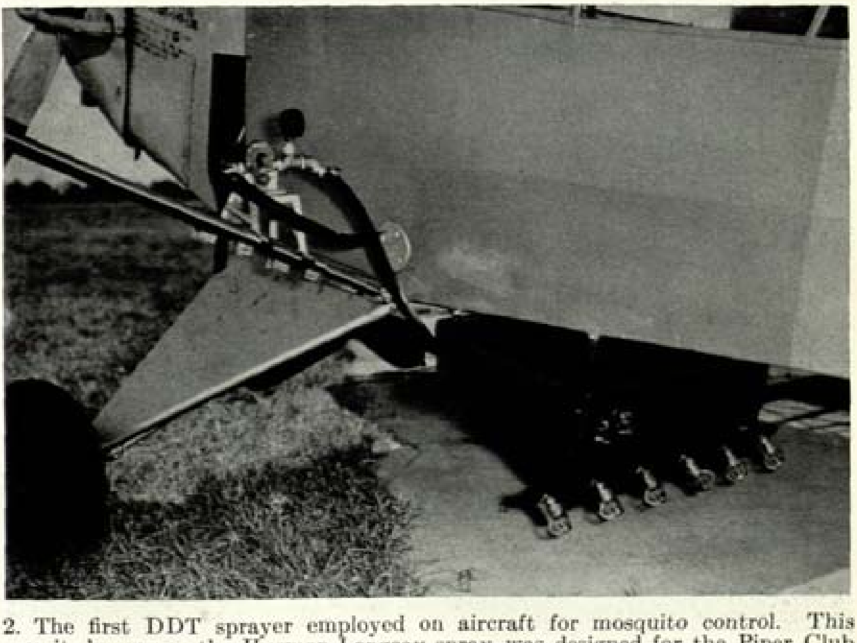
1. The body louse colony receives a blood meal. The lice clinging to the woolen pads placed on the back of the subject crawl beneath them and begin feeding almost immediately. The feeding process takes 20 to 30 minutes.

2. R. C. Bushland and E. F. Knipling examining treated "arm and leg" garments on research subjects to determine results of tests with insecticides for the control of body lice.

1. A scene in one of the *Anopheles* colony rooms. Margaret Greenwald and Jean McHarg are shown caring for the colony which was an important aspect of the mosquito research program.

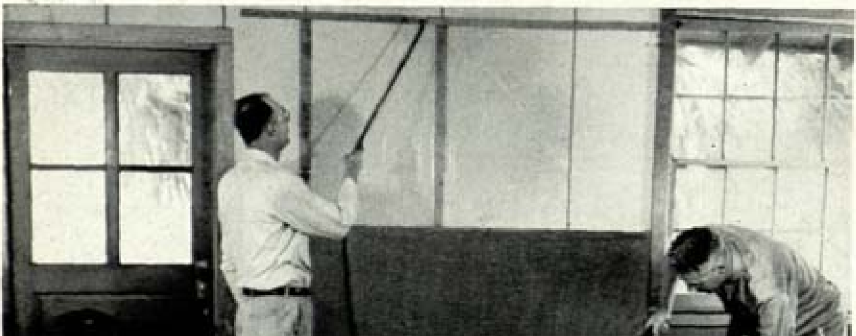
2. A scene in the larvicide testing room. Edna Hinchey is shown adding the desired concentration of a test chemical to water in a beaker prior to introduction of mosquito larvae.

1. Dusting with DDT. DDT applied as a dust was found to give good control, at dosages as low as 1 pound of active ingredient on 20 acres. Paris green, formerly used, required 1 pound per acre.

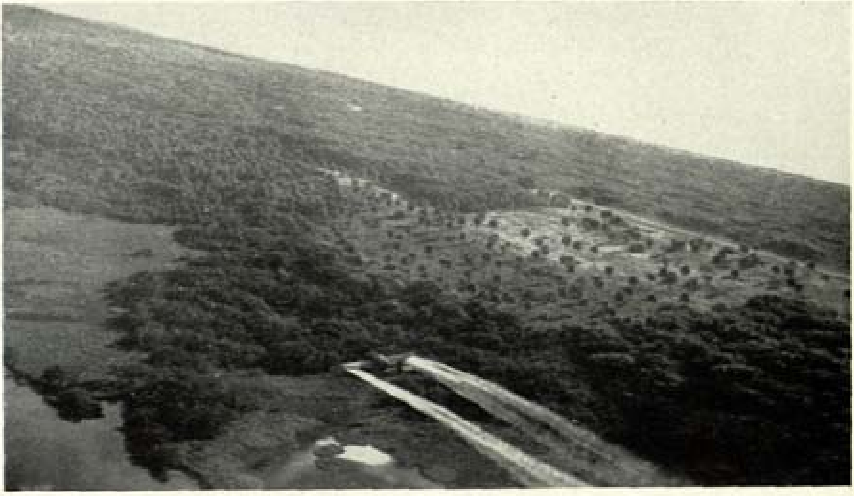


2. The first DDT sprayer employed on aircraft for mosquito control. This unit, known as the Husman-Longcay spray, was designed for the Piper Club (L–4). The equipped airplane was called the "Flying Flit Gun." It was employed primarily as an experimental unit.

One type of cage employed in conducting DDT laboratory tests. Various concentrations of DDT employing different kinds of formulations were tested as a residual treatment to determine the duration of effectiveness against mosquitoes and flies.



2. A. W. Lindquist and H. G. Wilson applying a residual or surface spray in an army installation. The development of the residual treatment principal of mosquito and fly control probably represents the greatest single advancement in our war on insect vectors of diseases.



1. Aerial photograph of Navy TBF airplane applying DDT spray along the Florida coast. The control of both larvae and adult mosquitoes over large areas represents a new method of mosquito control which few would have believed possible prior to the advent of DDT. The equipment on this plane was designed in cooperation with the Navy.

2. Laboratory test of insect repellent. Candidate insect repellents were first tested in the laboratory using caged mosquitoes. Here Dr. B. V. Travis has inserted his partially treated arm in a cage containing several thousand hungry mosquitoes.

1. B. V. Travis, A. W. Lindquist, A. H. Madden, and A. L. Smith with research subjects testing mosquito repellents in the field.

(U. S. D. A. photograph by Knell.)

2. Testing miticides. Several thousand candidate materials were tested. The initial test procedures consisted of "stopping time" tests. Here F. M. Snyder (center) and assistants are placing chiggers collected in infested areas on cloth patches treated with miticides to determine if they are effective miticides.

The Golden Nematode Invades New York

By W. L. Popham, *Assistant Chief, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture*

[With 2 Plates]

Of the many crop pests of foreign origin that have become established in the United States the golden nematode (*Heterodera rostochiensis* Woll.), which attacks the roots of potatoes and tomatoes, is potentially one of the most damaging, and certainly one of the most difficult to combat.

The golden nematode has been described as "a soil infesting organism, eel-like in shape, thin as the finest hair, and less than 1/50 of an inch long." In heavily infested soil thousands of them may attack the roots of a single potato or tomato plant. Upon reaching maturity the males die but the females, which have embedded themselves in the outer layer of the rootlets, eventually develop into tiny spherical cysts which may be seen with the unaided eye. These cysts may be white, cream, yellow, orange, or brown in color, according to age. Mature cysts, which are filled with eggs, usually become detached from the roots of the host plant and remain like weed seeds in the soil. When potatoes or tomatoes (the only known hosts) are again planted in the field a substance excreted from the roots stimulates fully developed larvae to hatch from the eggs and a new generation of nematode takes up the attack. Mature cysts may remain viable in the soil for at least 8 years without the presence of host plants.

Effect of Nematode First Observed in 1934

Just when or how the golden nematode gained entry to this country is not known. It is significant, however, that a potato grower near Hicksville, Nassau County, Long Island, N.Y., first became aware of its presence when a certain few spots in his field would not produce potatoes profitably even when he gave particular attention to normal cultural procedures for the area. In these spots the vines were stunted and off color. When harvested the potatoes were small, many no larger than marbles. This was in 1934. By 1938 these spots had multiplied both in number and size and, at a loss to account for the difficulty, the grower arranged for a soil analysis, suspecting that a mineral deficiency was responsible for his trouble. It was not until 1941, after infestation in the field had become much more general, that the real cause of the difficulty was determined to be golden nematode. During the remainder of that season an inspection of adjoining fields was made by the New York State Department of Agriculture and Markets and the Federal Bureau of Entomology and Plant Quarantine which added some 40 acres to the known infested area.

For the purpose of this discussion it will suffice to say that by 1945 the infested area had been extended to involve 34 properties totaling 1,080 acres. A year later infestation had been confirmed on 2,600 acres involving 81 properties, and an additional 3,000 acres, all in Nassau County, were known to have been operationally exposed. As of this

date (October 1948) the known infested area involves about 7,000 acres, all within 5 miles of Hicksville and all in Nassau County except three small fields comprising 30 acres just across the line in Suffolk County.

Because thousands of bushels of potatoes were grown and marketed without restriction from farms later found to be infested, there was speculation as to how generally distributed the golden nematode might have become. Also there was much speculation as to the amount of damage it might cause under normal cropping procedures in this country. What about soil fumigants? Was there an economical and practical way to "live with" the parasite should it become generally distributed in this country? Was there a simple way of disinfecting potatoes so that those grown on infested land could be allowed to move through normal marketing channels without creating a hazard of spread? There was an urgent need for research which would lead to answers to these and similar questions.

Survey Extended to Outlying Areas

In an effort to determine the distribution of the golden nematode in this country elsewhere than on Long Island, a carefully planned survey was organized by the Bureau of Entomology and Plant Quarantine in 1944 in cooperation with 19 of the more important potato-growing States east of the Mississippi River. In representative fields in centers of potato production as far west as Minnesota and North Dakota, plants were pulled and the roots examined. Particular attention was given to potato fields of poor stands or those with spots or streaks of unthrifty plants, and to areas around loading and grading points and waste dumps. More than 48,000 acres of potato land involving 1,500 properties in 148 counties were examined. No golden nematodes were found. Each year since then the survey on Long Island, elsewhere in New York, and in adjoining States, has been intensified using improved soil-sampling procedures but no infestation has been found beyond a 10-mile radius of Hicksville. This year particular attention has been given to surveys in New Jersey, Pennsylvania, Delaware, Maryland, and Virginia, with some additional work in New England and in States as far west as Wisconsin and Minnesota. It is encouraging that the "outside" survey for this season is now complete in most areas as far west as Ohio, and the results are negative.

Just what would it mean if the golden nematode became generally established in the more important potato-growing areas of the United States? Actually only a few fields have been permitted to become infested to the point that damage has been conspicuous. However, what has happened in these few fields coupled with the history of the pest in the British Isles and at other points in western Europe not only leaves little doubt as to its potential as a pest in this country, but focuses attention on the complete inadequacy of available methods of control.

When it was realized that several thousand acres of potato land on Long Island were infested, that eradication of the golden nematode with available tools was practically an impossibility, and that further spread of the parasite was inevitable unless drastic measures were taken, it was natural that we should look to Europe for available information on control. In November 1946 Dr. A. B. Buchholz, representing the New York State Department of Agriculture and Markets, and the writer, visited the British Isles and other points in western Europe to consult with scientists, potato growers, representatives of marketing associations, and others directly concerned with potato culture and marketing in areas where the golden nematode has been a major problem for a number of years. In our opinion the situation that exists in England today is sugges-

tive of what may be expected in this country eventually if the golden nematode is permitted to spread unchecked.

Potato-root Eelworm (Golden Nematode) Has Spread Rapidly in England

Information obtained in conferences with more than 40 scientists, farm advisers, farm managers, and farm foremen in England, Ireland, and Holland indicated that the more important factors contributing to the spread of the golden nematode were (a) using potatoes produced on infested soil for seed, (b) moving transplants from infested soil to other fields, (c) using the same farm implements and containers interchangeably in infested and noninfested fields, (d) soil drifting from infested to noninfested fields, and (e) the careless disposal of containers used in handling culinary potatoes grown on infested lands.

It was learned that the golden nematode, or potato-root eelworm as it is commonly called in Europe, is prevalent in 65 to 75 percent of the fields in the more important potato-growing areas of England. It is reported to occur wherever potatoes are grown commercially in Scotland. In northern Ireland the parasite is not widely distributed. However, some 300 acres known to be infested at that time had been taken out of potato and tomato culture by the Ministry of Agriculture which has authority to remove from production promptly any fields determined to be infested, even when such action involves destruction of a crop. A similar situation exists in Holland. Only limited areas are reported to be infested and these have been dealt with drastically. Both Holland and northern Ireland have undertaken to protect export seed industries which are based to an important degree upon certification that the potatoes are grown on eelworm-free soil.

Golden Nematode Now Recognized as Major Pest in Europe

Research on the potato-root eelworm in recent years has been intensified in Europe owing to the extensive damage that is now attributed to it. In talking with research workers at St. Albans, Cambridge, and Leeds, in England, and at various points in Holland it was learned that European investigators were primarily concerned with (a) a search for a fumigant which would effectively and economically reduce the eelworm population in an infested field to a level where potatoes or tomatoes could be grown profitably, (b) a search for resistant host material, (c) a search for a synthetic which would stimulate hatching of the larvae in the absence of host material, thus shortening the host-free period required to suppress or eradicate the parasite, (d) a search for chemicals having a retarding effect on cyst development, and (e) the extension of a publicly provided soil-examination service undertaken during the war to indicate fields in which the cyst count was at a sufficiently low level to insure a profitable crop of potatoes. Because the golden nematode has become so widely distributed in England most investigators there were concerned more with ways of growing potatoes in competition with it than in developing practical methods for eradication or prevention of spread.

A few quotations may help in an appraisal of the seriousness of the pest in England. J. Wood reports as follows in the September 1946 issue of The Kirton Agricultural Journal:

> The total acreage of infested land in the county (Holland, Lincolnshire) is not definitely known, but from different estimates it is believed to be about 20 percent of the total arable. This means that trouble has occurred on about 40,000 acres during the past 25 years. It does not take into account the land that is already initially infested or contaminated. On a few farms every field is infested and potatoes cannot profitably be grown. On some, most of the fields are infested and the potato acreage has had to be reduced;

while on a large number of farms one or two infested fields are being rested from potatoes and the directed acreage is being grown on the remaining land by more intensive cropping. * * *

No information is available concerning the total acreage of infested land that is being cropped after being rested, but it can be stated that 25 percent of the failures occurred on such land because the resting period had been too short. In some instances farmers had concluded that a rest of 3 years ought to be sufficient, in others they had had a good crop a year or two earlier after a long rest and thought that the pest had been starved out. But the most distressing instances were the few where the trouble showed up in patches after a rest of 7 or 8 years.

With regard to a remedy, Mr. Wood has the following to say:

Farmers are naturally anxious to learn what steps have been taken to discover some means of controlling this eelworm, and it may be mentioned in this connection that when the Holland County Council purchased the Agricultural Institute Farm they were soon confronted with this problem at Kirton. No time was lost in calling in available specialists to carry out an investigation. South Lincolnshire was not the first potato-producing area to experience the trouble, but because of the importance of potatoes to the county, and the fact that a County Advisory Service had recently been introduced, experiments were soon in progress. Hopes of success were high when a dressing of drained creosote salts applied at the rate of 8 cwts. per acre and ploughed in 14 days before planting gave a big increase of crop. But after several years it became obvious that the treatment was unreliable and its recommendation was discontinued. Since then research work has continued at the Institute of Agricultural Parasitology on fundamental points in the life-history and responses of the pest. A vast amount of information has been accumulated but the search for some material suitable for application to the soil still goes on. Meanwhile the only effective recommendation is that of resting the land from potatoes for a suitable period. And that suitable period has still to be worked out locally.

In summarizing he points out that—

There is as yet no instance on record in the county where main crop potatoes have been grown successfully even once in 4 years when a crop has once failed without the trouble again becoming eventually evident. In the absence of some helpful control measure it is not unlikely that a 6-year rotation will have to be adopted.

The following appears in Leaflet No. 117 published by the Ministry of Agriculture of Northern Ireland in December 1945:

Potato root eelworm is now regarded as the most serious pest affecting the potato crop in many of the main potato-growing areas in Great Britain. Because of its slow development, its seriousness, and even its presence, are often not realized until there is a very great reduction in crop yields. The pest may be regarded as more serious than the well-known Black Scab disease, because all varieties of potatoes are subject to attack and there is no known cure under field conditions. Once land becomes infected it remains so for a long period. How long is not known.

The first symptoms of eelworm attack are the appearance of a patch or patches in the crop where the plants are dwarfed and sickly —not unlike a patch produced by a wet spot in a field or even by other diseases. The plants have weak, spindly stems, and the tops are generally stunted and paler in color than those of the rest of the crop. The leaves are under-sized and have a tendency to wilt and to drop off prematurely. The lower leaves wither at first but the whole top eventually collapses early in the season. As these plants die off, the attack spreads to the healthier plants around the margins.

The author has the following to say in regard to preventive measures:

There is no effective means of destroying the eggs of the eelworm in the field and it is, therefore, of the utmost importance that everything possible should be done to prevent clean land from becoming infected. Two essentials toward this end are (a) to use only certified eelworm-free seed, and (b) to adopt a wide rotation on the farm in which potatoes do not occur more than once every 5 years. Eelworm attack nearly always occurs when potatoes are grown frequently in the same field. Farmers should, therefore, avoid this practice at all costs, even should this mean limiting their area under potatoes.

It has been clearly demonstrated that golden nematode cysts will remain in the soil for 8 or more years without the presence of host plants. Therefore, any natural or mechanical movement of soil from infested fields during that time may result in its spread to new areas. Soil fumigation with materials now available will substantially reduce but not eradicate infestation and such treatment is costly and provides only temporary relief.

Known Infested Land Held Out of Potato Production

There are now known to be somewhat more than 7,000 acres in the Hicksville area either infested or exposed to infestation. In complying with the provisions of the New York State quarantine and in accordance with a carefully organized Federal-State cooperative control program, known infested acreage was held out of production during the 1948 season with the understanding that growers would receive compensation amounting to approximately two-thirds of their losses, these to be calculated on the basis of average crops over a 5-year period.

As a result of inspections made on Long Island since planting date, infestation has been found on an additional 800 acres, all of which is very lightly infested. However, potatoes from these fields and from adjacent exposed fields will be marketed through approved channels under supervision as heretofore.

The Hicksville area represents less than 10 percent of the land normally planted to potatoes on Long Island so the prevention of local as well as long-distance spread is an important consideration. It is recognized that before the golden nematode was known to occur on Long Island, potatoes from infested fields moved to market without restriction. However, Long Island is not a seed-producing area, and potatoes grown there are consumed for the most part in New York City or in other metropolitan areas. It is possible, however, that some may have found their way to rural points. Bags used in marketing potatoes from infested fields may have reached the hands of potato growers in areas some distance from Long Island. Thus, while the Bureau is cooperating closely with the State of New York in maintaining strict control over the movement of potatoes or other soil-bearing objects from infested lands on Long Island, it is important that potato growers and pest-control officials throughout the country remain alert to the possibility that the golden nematode may have become established elsewhere. If such foci of infection exist it is important that they be discovered promptly and that suppressive action be taken. At least until far more statisfactory methods of control are known, it is highly important that further spread of the pest be prevented.

Cornell University and the Bureau of Plant Industry, Soils, and Agricultural Engineering are cooperating in a comprehensive research program which has two main objectives: (1) to find a practical method of disinfesting potatoes grown on infested lands so that they may move to market without restriction as to destination, and (2) to determine a more effective and economical soil treatment which can be used either in an eradication effort or for commercial control in areas where the nematode now occurs or later becomes established.

Some modifications will be made in the cooperative control program for 1949. However, the main objective will be to keep out of potato and tomato production as much as possible of the land known to be infested.

Known Infested Land Held Out of Potato Production

There are now known to be somewhat more than 7,000 acres in the Hicksville area, either infested or believed to be infested. In conformance with the regulations of the New York State quarantine and in accordance with a generally accepted Federal-State program of control, production of susceptible crops was held out of production during the 1948 season with the understanding that growers would receive compensation amounting to approximately two-thirds of their losses, these to be calculated on the basis of average crops over a 5-year period.

As a result of inspections made on Long Island since planting date, information has been found on an additional 600 acres, all of which is very lightly infested. However, potatoes from these fields and adjacent exposed fields will be marketed through approved channels under supervision as heretofore.

The Hicksville area represents less than 10 percent of the land annually planted to potatoes on Long Island, so the prevention of local as well as long-distance spread is an important consideration. It is considered that before the golden nematode was found on Long Island, potatoes from infested lands were [illegible] to [illegible]. However, Long Island [illegible] and potatoes generally are consumed for the most part in New York City or in other metropolitan areas. It is possible, however, that some may have found their way to rural points. Bags used in marketing potatoes from infested fields may also have reached the hands of potato growers in areas some distance from Long Island. Thus, while the Bureau is cooperating closely with the State of New York in maintaining strict control over the movement of potatoes or other [illegible] from the infested area on Long Island, it is [illegible] potato growers and pest-control officials throughout the entire country alert to the possibility that the golden nematode may have become established elsewhere. Should an infestation exist it is important that it be discovered promptly and that suppressive action be taken. At least until more satisfactory methods of control are known, it is highly important that further spread of the pest be prevented.

Cornell University and the Bureau of Plant Industry, Soils, and Agricultural Engineering are cooperating in a comprehensive research program which has two main objectives: (1) to find a practical method of disinfesting potatoes grown on infested lands so that they may move to market without restrictions as to destination; and (2) to determine a highly effective and economical soil treatment which can be used either in an eradication effort or for commercial control in areas where the nematode [illegible] of [illegible] established.

Some modifications will be made in the cooperative control program for 1949. However, the general objective will be the removal of potato and tomato production as much as possible on the land known to be infested.

GOLDEN NEMATODE, HICKSVILLE, L. I., N. Y., 1946

Roots of potato plant showing golden nematode cysts (enlarged).

1. GOLDEN NEMATODE, HICKSVILLE, L. I., N. Y., 1946

Soil sampling for golden nematode. Inspector lifting soil sample on trowel and placing sample in paper bag.

2. LABORATORY WORKERS WITH BINOCULARS EXAMINING A SYRACUSE DISH CONTAINING RESIDUE FROM A SOIL SAMPLE IN ORDER TO DETERMINE THE PRESENCE OF GOLDEN NEMATODE CYSTS

The Cork Oak in the United States

By Victor A. Ryan, *Director of Research, Crown Cork and Seal Company, Inc.*, and Giles B. Cooke, *Director of McManus Cork Project, Research Department, Crown Cork and Seal Company, Inc., Baltimore, Md.*

[With 8 plates]

The cork tree is a species of oak which is known botanically as *Quercus suber*. The wood is light in color and the cork oak has been considered to be of the white oak variety. Recently Williams (1) [1] has shown the wood of the cork tree possesses grain structure similar to that of the red oak.

Cork is the bark of the cork oak tree which is native to the small area that forms the shores of the western Mediterranean. When the tree is 20 years old or about 9 inches in diameter, cork is stripped from the trunk. New cork grows to replace that removed, but much faster than the original bark, and subsequent strippings of the cork tree are made every 8 to 10 years. The bark after being boiled, scraped, dried, and baled is the cork of commerce. For more than 2,300 years the world's supply of cork has come from Europe and North Africa.

The United States uses more cork than any other country. Cork is very important to our national economy, for it is both a critical war material and an essential peacetime commodity. To meet this Nation's manufacturing requirements approximately 160,000 tons of corkwood are imported annually. From this cork many important articles are produced. These include bottle stoppers, life preservers, ring buoys, floats, shoe inner soles, sealing liners for bottle caps, gaskets of many types for automobiles, electric motors, switch boxes, household appliances and other articles, friction rolls, polishing wheels, and corkboard for insulation, acoustical and machinery isolation purposes.

[1] Numbers in parentheses indicate references at the end of this article.

Early Plantings in the United States

The founders of our country were aware of the importance of cork. At the same time they knew the cork tree could be grown in the South and possibly elsewhere in the United States. As early as 1787 Thomas Jefferson sent cork acorns from France to William Drayton of "Magnolia" at Charleston, S. C. No cork trees resulted from this planting, but Thomas Jefferson continued to recommend and urge the planting of cork trees until his death in 1826.

While the records indicate no cork trees were established by Thomas Jefferson, his efforts to introduce this tree in the United States were not in vain. Interest in the cork oak had been aroused, and in 1858 the Federal Government obtained cork acorns from Spain and distributed them in the South and in California. Some trees were obtained from this planting, but many of them were lost through lack of care, drought, and other causes. Again in 1880 cork acorns were imported, and a few additional cork trees were obtained. In 1914 the

Federal Government brought in cork acorns which were planted in South Carolina and Florida. A number of cork trees were started, but fire and storms resulted in total loss. Some plantings have been made during the past 75 years through private and State efforts. About 600 trees were planted at Chico, Calif., by the University of California in 1904. Private plantings have been made in Arizona, California, Washington, and the southern States.

The McManus Cork Project

Some time ago the late Charles E. McManus, former president and chairman of the board of the Crown Cork and Seal Co., examined some of these domestic cork trees. Having visited the cork forests of Europe and Africa on numerous occasions, Mr. McManus at once recognized the good quality of the cork, and more trees were inspected. With more than 30 years of successful experience in manufacturing cork products he realized the great value of having cork trees grown in this country. Plans were made to remove the cork from some of the trees for thorough testing and to collect cork acorns for planting. A Cork Project was established by Mr. McManus to promote the growing of cork trees in the United States. The Cork Project is designed to add to the natural resources of our country and to provide in the United States a source for at least a part of the Nation's cork requirements.

The McManus Cork Project was initiated in California where a substantial number of mature cork trees are growing. These cork trees are in parks, along highways, about public buildings, and on private property. Arrangements were made with local and State authorities and private owners for the experimental stripping of many of these trees. In 1940 5¼ tons of virgin cork were removed from California cork trees. The same year approximately 500 pounds of cork acorns were collected for planting. During the winter Mr. McManus located mature cork trees in Arizona, and in 1941 the Cork Project was extended into that State. More cork trees were stripped in 1941 and over three-quarters of a ton of acorns collected for planting. Because of the interest and enthusiasm shown by landowners, Mr. McManus early in 1942 expanded the Cork Project to include the South and all States where climate, soil, and other factors were favorable to the cork tree. The McManus Cork Project had developed rapidly into a Nation-wide cork-growing program.

ORGANIZATION AND YEARLY PROGRAM

The Cork Project has received the enthusiastic support of foresters throughout the country. The United States Forest Service, State departments of forestry, schools of forestry in the universities, extension foresters, vocational agriculture teachers, and local agricultural agents are cooperating with the project. Their cooperation and knowledge of tree culture has contributed greatly to the splendid progress that has been made.

Searching for old mature cork trees was one of the first tasks. These trees are needed for acorns and experimental stripping. Also, it is important to know where mature cork trees are growing in this country. The locations of the mature cork trees indicated where cork plantings could immediately be made. It is obvious that cork trees can be grown where old cork oaks have thrived for many years. Approximately 4,000 cork trees have been found in California, extending from Humboldt County in the north to San Diego County in the south. A grove of 600 cork trees planted in 1904 is growing at Chico. Fresno has several hundred cork trees at Kearney Park and throughout the fig garden area. In Los Angeles County more than 1,000 mature cork trees are located.

Arizona has about 40 cork trees with the largest number in and near

Phoenix. In the East and South a limited number of cork trees have been found in the States of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Louisiana, and Texas. Some of these trees produce only a few acorns, and annual cork acorn collections have been concentrated in California. Experimental stripping has been carried out in California, Arizona, and the South.

PLANTING ACTIVITIES

One of the very first problems was the proper handling of the cork acorns which mature in November and December. Storage tests showed cork acorns could be kept viable for several months in wet cold storage at 34° to 38° F. This method has been used successfully with large quantities of acorns for the past 5 years. As soon as collected, the acorns are shipped to cold-storage plants in New Orleans and Baltimore. For the Deep South the acorns are distributed early in February. Other States receive the acorns late in February and early in March. Those States on the northern border of the cork-growing area receive the acorns about the last of March or the first of April.

Cork acorns are sent to the forestry departments of all the cooperating States. A portion of the acorns are planted in the State forest nurseries to produce seedlings for distribution later on. The balance of the acorns are distributed promptly to interested landowners throughout the States for immediate planting. In several States, through the cooperation of the extension foresters, cork acorns are shipped to the county agents who distribute them among 4–H Club members. Vocational agriculture teachers are cooperating in the Cork Project by distributing acorns to F. F. A. and F. H. A. members. Science clubs affiliated with Science Service, garden clubs, and other civic organizations are growing cork trees.

Most of the plantings are of limited size where the cork tree is being grown as an ornamental on lawns or a shade tree about farms. In some cases several acres have been planted. A number of colleges and universities are growing groves of cork trees of 1 acre in size or larger. Statewide Arbor Day programs, during which a cork tree was planted at the county seat of each county, have been held in South Carolina and Georgia. Recognizing the importance of the cork tree to this country, governors of 11 States have planted cork trees on the grounds of their respective capitols.

RESEARCH

Numerous research activities are carried out by the McManus Cork Project. The cork oak has been successfully grafted to native oaks. Mirov and Cumming (2) have shown that scions of the cork tree can be grafted to both evergreen and deciduous American oaks. This method of establishing cork trees is under observation and it will be some time before the complete story is known.

The rooting of cuttings is another method of propagation that has received serious attention. Cuttings from old mature cork trees have been rooted at the Fruitland Nurseries, Augusta, Ga. Tests are being continued until the method can be reduced to a routine. Cuttings for rooting tests, like the scions for grafting, are taken from trees having thick, resilient cork and bearing large crops of acorns.

Experiments are being conducted on the rate of growth of cork trees. Cork seedlings in sand are being grown in the presence and absence of plant-food elements. This research will help in bringing the cork tree to stripping size in the minimum of time.

The cork oak develops a long tap root with few laterals and this makes bare root seedlings difficult to transplant successfully. Research on root pruning cork seedlings in the nursery has been in progress several years. These tests already show more profuse root-development results from the first pruning. A much higher percentage

of survival should result from these experiments.

It is well known that top-grade cork is obtained only with the third and subsequent strippings. Accordingly, a cork tree is about 35 years old when first-grade cork can be harvested. Experiments to reduce this time are in progress. Second-growth cork has been removed after 6 years instead of the usual 8- to 10-year period. Also, young cork trees 8 to 10 years old have been stripped. Second-growth cork will be removed after an interval of 7 years.

Other experiments conducted on cork oak culture concern the best season for planting, auxins, and other factors. However, the extensive annual planting of the cork tree throughout many sections of 27 States constitutes the largest research work of the Cork Project. Seedlings and acorns are planted under widely varying temperature, rainfall, and soil conditions. Factors such as planting technique, the best planting month, sunshine, and drainage are getting a thorough test. A storehouse of valuable data is being built and at the same time thousands of cork trees are being established.

ACCOMPLISHMENTS

The progress made since the initiation of the McManus Cork Project is very gratifying. From a few experimental plantings in 1940 the Cork Project has grown to include extensive plantings in 27 States. Thousands of small cork trees are growing throughout the warmer half of the United States and tons of acorns are planted annually in the potential cork areas of this country. With the helpful cooperation of Federal and State foresters and the aid of local vocational agriculture teachers and county farm agents, the Cork Project has passed the trial stage successfully. The past 8 years of successful work give confidence and efficiency to those planting and growing cork trees.

The number of cork plantings that can be made each year depends upon the quantity of cork acorns available. When the acorns have matured and dropped from the trees, they are collected and placed in wet cold storage. The acorns are picked up to avoid dead leaves, sticks, and other material which would cause mold and rotting. For the past several years the entire domestic cork acorn crop has been harvested, and requests for seed greatly exceed the available supply. Distribution of cork acorns during the past 8 years is given in the following table:

Year	*Pounds of acorns*
1940–41	500
1941–42	1, 450
1942–43	7, 500
1943–44	7, 900
1944–45	13, 800
1945–46	10, 200
1946–47	14, 812
1947–48	*7, 876

*Small crop of California cork acorns in 1947-48.

All these acorns, except approximately 200 pounds collected annually in Arizona and the South, were obtained in California. When taken from storage, they are shipped in burlap sacks in about 100-pound lots to the cooperating State foresters. For clubs and organizations from 10 to 20 pounds of acorns are packed with moist sawdust in waterproof cartons. Individuals receive from ½ to 2 pounds which are packed moist in waterproof boxes to prevent drying.

Because of the huge quantity of acorns and large number of individuals planting them, a check on the plantings is as yet very incomplete. However, a partial check on Florida plantings in 1946 showed more than 1,000 young cork trees were growing in that State. Reports for a portion of the Future Farmers of America in Georgia show this group of young people obtained over 1,000 cork trees from their 1947 plantings alone. The F. F. A. members in Georgia have planted cork trees the past 4 years. An incomplete survey in Oklahoma

indicates several thousand cork trees are growing in this State. Excellent specimens of young cork trees 6 to 8 years old are now growing in California, Arizona, Texas, Arkansas, Alabama, Mississippi, and elsewhere in the South. In all the cooperating States encouraging progress has been recorded indicating that the cork tree can be grown successfully when planting conditions are favorable.

Since the initiation of the McManus Cork Project more than 600 cork trees have been stripped of virgin cork. Most of these trees are in California but cork has been removed from approximately 20 trees in Arizona and the southern States. This cork has been manufactured into cork products and given standard tests. Composition cork and corkboard insulation manufactured from the domestic product were of excellent quality. Growth of reproduction cork on the stripped trees is very satisfactory. Almost 1 inch of second growth is obtained in 6 years on 35-year-old trees. With older trees the growth was even greater. The following table gives a summary of cork stripping by years:

Year	Number of trees stripped	Yield of cork (lbs.)
1940	248	10, 561
1941	47	2, 142
1942	63	3, 466
1943	46	2, 735
1944	54	3, 216
1945	58	3, 538
1946	46	2, 882
1947	61	2, 803

Geographic and Economic Studies

Although there are upward of 4,000 old cork oaks and nearly a million new plantings scattered in 24 States, we must face the fact that the cork oak is not yet grown in the United States in commercial quantities and that we are virtually without experience in its growth as a crop. Therefore, before a cork-forest industry becomes a reality in this country, there is much to be done in the way of organized research and systematic planning in order to establish the essential foundations for such an industry.

At this particular stage of development, the most essential requirement for the botanic and economic success of a cork-forest industry appears to be the selection of suitable areas in which to grow the trees in order that the cork oak in the United States will be provided with a geographic ecology identical with that of the Mediterranean region and will not be required to adapt itself to a new or foreign climate, but will be free to grow and produce in response to the same laws of Nature as those prevailing in its natural habitat. A hypothesis as to such suitable areas was developed after the completion of a comprehensive geographic study of the natural distribution of the cork oak in relation to the climatic factors of temperature, rainfall, and soil, which is described in detail in "Some Geographic and Economic Aspects of the Cork Oak" (3), from which the following is condensed.

Geographic Distribution of the Cork Oak

The world's commercial supply of cork, which averages, at the present time, about 350,000 short tons per year, is grown in the approximate 5,015,000 acres of cork oak forests bordering the Mediterranean Sea. The entire area is known as the Mediterranean region and comprises Portugal, Spain, France and Corsica, Italy, Sicily and Sardinia, Tunisia, Algeria, French Morocco and Spanish Morocco. The total cork-forest area of this region is approximately 7,950 square miles.

The locations of the cork-growing areas within each Mediterranean country are shown in figure 1 and the facts and figures of distribution and production are listed in table 1.

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TABLE 1.—*Mediterranean region—cork oak acreage and cork products, 1936*

Area		Country	Annual production		
Percent of total	Acres		Short tons	Percent of total	Yields (pound-acre)
33.8	1,720,000	Portugal	130,000	46.2	151
12.2	622,000	Spain	66,000	23.1	212
6.9	350,000	France-Corsica	13,200	4.8	75
4.9	247,000	Italy-Sicily-Sardinia	8,800	3.2	71
4.6	235,000	Tunisia	7,400	2.6	63
21.6	1,100,000	Algeria	38,500	13.8	70
14.6	741,000	French Morocco	17,600	6.3	48
1.4	74,000	Spanish Morocco			
100.0	5,089,000	Mediterranean region	281,500	100.0	112

Key to Figure 1

I. PORTUGAL

Number — *Province*

1. Beja
2. Setubal
3. Evora
4. Portalegre
5. Santarem
6. All others

II. SPAIN

1. Granada
2. Malaga
3. Cadiz
4. Huelva
5. Sevilla
6. Cordoba
7. Ciudad Real
8. Badajoz
9. Càceres
10. Toledo
11. Avila
12. Salamanca
13. Coruna
14. Santander
15. Gerona
16. Barcelona
17. Castellon

III. FRANCE

Department

1. Landes
2. Lot-et-Garonne
3. Pyrenees-Orientales
4. Var
5. Alpes-Maritimes
6. Corsica

IV. ITALY

Number — *District or Province*

1............ Sardinia
1–A........ Sassari
1–B........ Nuoro
1–C........ Cagliari
2............ Tuscany
2–A........ Pisa
3............ Latium
4............ Compania
4–A........ Salerno
5............ Apulia
6............ Calabria
7............ Sicily
7–A........ Trapani
7–B........ Palermo
7–C........ Messina
7–D........ Catania
7–E........ Syracuse

V. TUNISIA

Region

1. Mogods
2. Khroumiria

VI. ALGERIA

1............ Dep. of Constantine
1–A........ Souk-Ahras
1–B........ Jemmapes
1–C........ Sidi-Meroun
1–D........ Philippeville
1–E........ Collo
1–F........ El Melia
1–G........ Djidjelli
1–H........ Bougie
1–J........ Jebel (Mts.) of Babors
1–K........ Bona
1–M........ La Calle

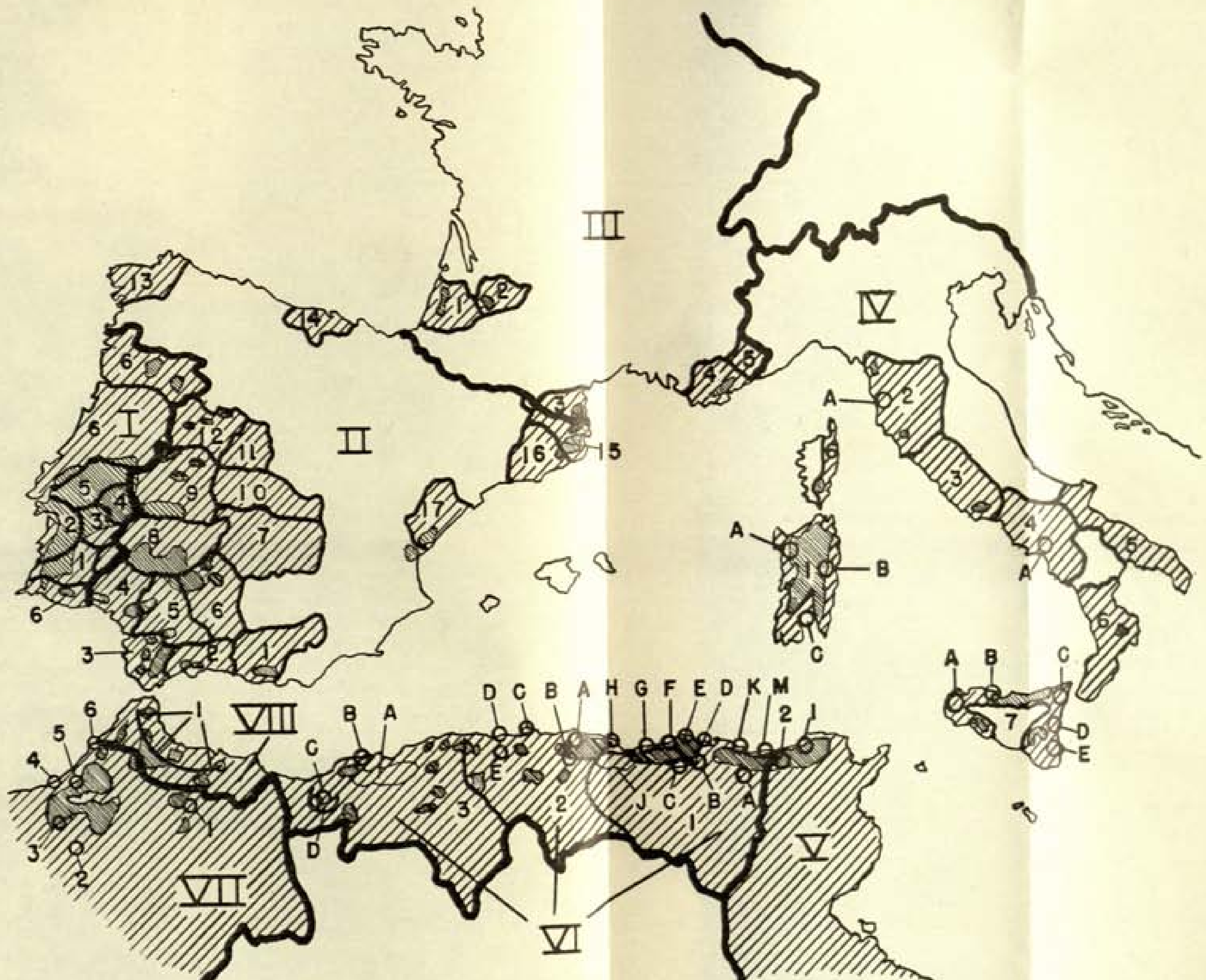
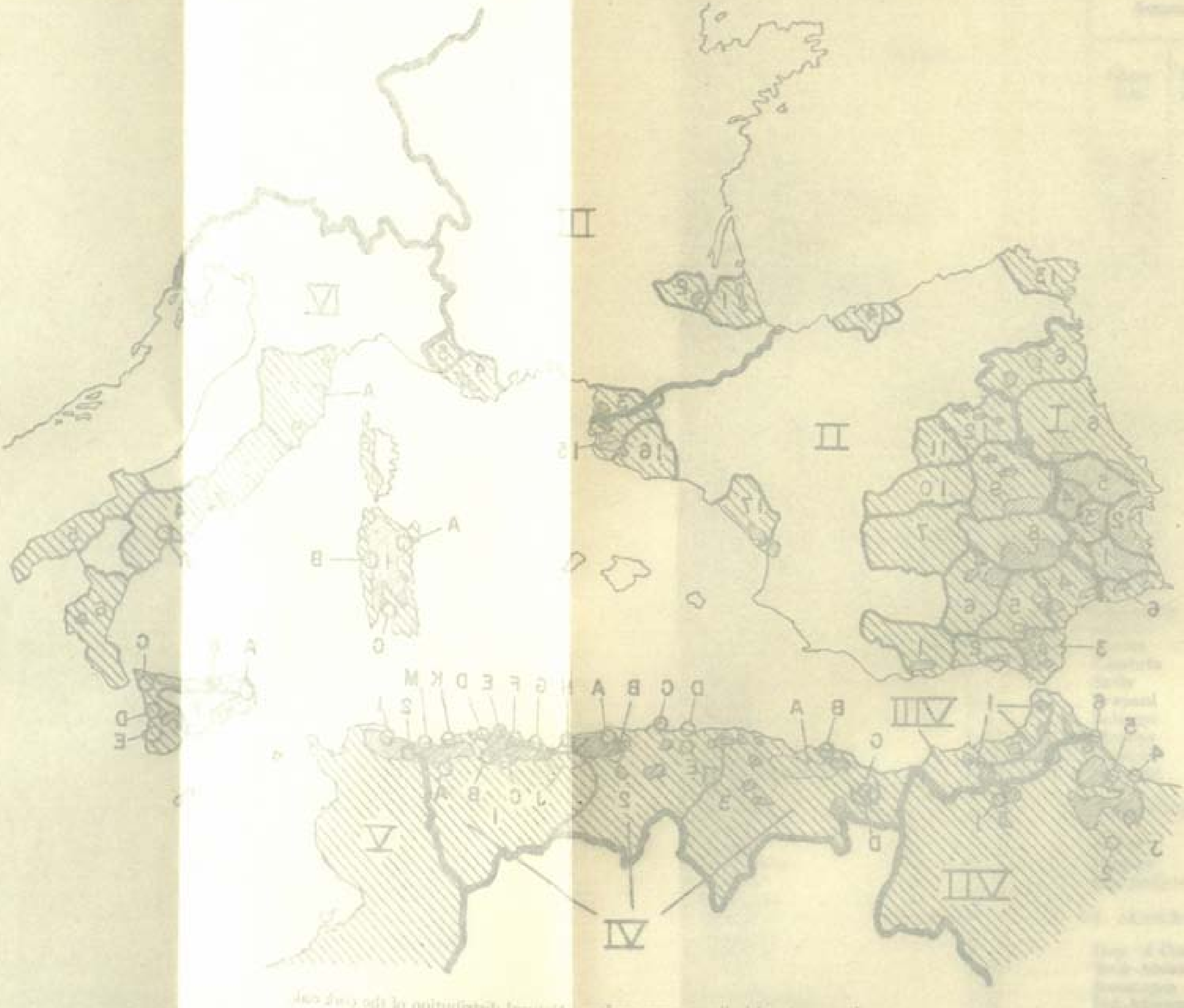


FIGURE 1.—Mediterranean region. Natural distribution of the cork oak.

Cork-growing provinces, districts, and regions as described in "World Production and Trade in Cork," Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce, 1937.

Approximate location of cork forests, from "Map Showing Natural Distribution of the Cork Oak and Location of Important Cork Oak Forests," by P. L. Buttrick, Forestry Department, Armstrong Cork Co., Lancaster, Pa., 1931.



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Approximate location of cork forests, from "Map Showing Natural Distribution of the Cork Oak and Location of Important Cork Oak Forests," by P. L. Buttrick, Forestry Department, Armstrong Cork Co., Lancaster, Pa., 1931.

Number	*Region*
2............	Dep. of Algiers
2–A........	Drael-Mizan
2–B........	Bouira
2–C........	Algiers
2–D........	Cherchel
2–E........	Militana
3............	Dep. of Oran
3–A........	Sahel of Oran
3–B........	Oran
3–C........	Tlemcen
3–D........	Jebel Tlemcen

VII. FRENCH MOROCCO

1...........	Taza, near forest of Bab Azhar
2...........	Tedders, near groves of The Zemmour
3...........	Marchand, near groves of The Zaer
4...........	Sale, near forest of The Schouls
5...........	Mamora
6...........	Moulay Bou-Selham, near Forest of Gharb

VIII. SPANISH MOROCCO

1...........	Line of the Riff Mountains

All statistical data relating to the distribution of the cork oak and to the production of cork in the Mediterranean region and its constituent countries were either taken or computed from the Bureau of Foreign and Domestic Commerce report, "World Production and Trade in Cork" (4). With a few exceptions, the authentic facts and figures listed in the publication are for the year 1936 and represent the latest available information.

Portugal is the largest producer of cork, supplying 46.2 percent of the world's tonnage from 33.8 percent of the total acreage.

Although the cork oak is distributed throughout the entire country, the major portion of its cultivation is concentrated in the south-central region. The 1,720,000 acres of Portugese cork oak forests are distributed as follows: 6.9 percent in the Province of Beja, 13.3 percent in Setubal, 27 percent in Evora, 20 percent in Portalegre, 19.7 percent in Santarem, and 13.1 percent in all other provinces.

Spain ranks second with respect to cork production, furnishing 23.1 percent of the world's tonnage from 12.2 percent of the total acreage. The cork groves of Spain are located principally in southern Andalusia, in Extremadura, and in northwestern Catalonia. The 622,000 acres of Spanish cork groves are distributed as follows: 6.8 percent in the Province of Malaga, 24.1 percent in Cadiz, 12.0 percent in Huelva, 10.8 percent in Sevilla, 14.4 percent in Badajoz, 9.5 percent in Cáceres, 14.3 percent in Gerona, and 8.1 percent in other provinces.

Of the other provinces, Cordoba, Ciudad Real, Toledo, Barcelona, and Castellon possess mountain areas in cork, while noncommercial quantities are found in Granada, Avila, Salamanca, Coruna, and Santander.

France is one of the smaller cork-producing countries supplying only 4.8 percent of the world's production from 6.9 percent of the total acreage. The distribution of the 350,000 acres of French cork oak forests is 87 percent among the Departments of Landes, Lot-et-Garonne, Pyrenees-Orientales, Var, and Alpes-Maritimes, and 13 percent in Corsica. The Department of Var is by far the richest cork area in the country, furnishing about 75 percent of the French cork. Corsica ranks second in importance.

Italy is also one of the smaller cork-producing countries, furnishing only 3.2 percent of the world's supply from 4.9 percent of the total acreage. The largest and best cork oak groves are in Sicily and Sardinia; the smaller groves are in Italy proper. Of the 247,000 acres of Italian cork groves, 14 percent are in Italy, 16 percent in Sicily, and 70 percent in Sardinia.

In Italy, the largest commercial groves are in the Districts of Tuscany, Latium, and Compania; other isolated growths are located in the Districts of Apulia and Calabria and in the provinces around Pisa and Salerno. The Sicilian groves are around Trapani, Palermo, Messina, Catania, Syracuse, and Enna while the cork oak areas of Sardinia are chiefly in the Provinces of Sassari, Nuoro, and Cagliari.

Tunisia is the smallest of the cork-producing countries containing only 4.6 percent of the total acreage from which 2.6 percent of the world's supply is obtained. The approximate 235,000 acres of Tunisian cork oak forests are situated in the northwestern coastal regions of Khroumiria, the Nefzas, and the Mogods.

Algeria is the third largest cork-producing country. It furnishes 13.8 percent of the world's tonnage from 21.6 percent of the total acreage. The cork oak forests are located principally in the shore zone and Tell regions but there are some relatively small areas in the highlands. The 1,100,000 acres of Algerian cork forests are distributed as follows among its three Departments: Constantine, 89 percent; Algiers, 9.3 percent; and Oran, 1.7 percent.

In the Department of Constantine, the principal cork centers are LaCalle, Bona, Philippeville, Collo, Djidjelli, and Bougie. The cork oak forests are situated in Souk-Ahras, Little Kabylia, Sidi-Meroun, the Jebel (mountains) of Babors near Bougie, the forests of Bessombourg and Cheraia in the Goufi Mountains, in El Melia and Jemmapes near Philippeville, and in l'Edough near Bona.

In the Department of Algiers, the principal cork center is the city of Algiers. The cork oak areas are located in Bouira, in the forests of Drael-Mizan, Yakouren, and d'Azazga in Great Kabylia, and in the regions of Cherchel and Militana.

In the Department of Oran, the principal cork oak forests are in the regions of the Sahel of Oran and Tlemcen.

French Morocco is the fourth largest cork-producing country, containing 14.6 percent of the world's acreage from which 6.3 percent of the total tonnage is obtained. The cork-producing regions constituting its 741,000 acres are located in the forests of Bab Azhar near Taza, the Sehouls near Sale, and the Mamora, Gharb near Moulay Bou-Selham, and Boulhart; and in the groves of Zemmour near Tedders, Harcha, Oulmes, Ouldjet Soltane, the Zaer near Marchand, the M'Dakra near Boucheron, the Achach, the Gnadis, and the region of Moulay Bou Azza.

Spanish Morocco is not a cork-producing country at the present time. Its economic position is that of the potential rather than the actual. The cork-growing areas, which constitute 1.4 percent of the world acreage, have not been put into production since the second Riff war, owing to disputes among tribes, individuals, and the Moorish state, about ownership. Its production potentiality has been estimated at approximately 6,600 short tons per annum which would be equivalent to 2.3 percent of the world production.

The approximate 74,000 acres of cork oaks are distributed among some eight forest patches mainly along the line of the Riff Mountains.

Climatic Distribution of the Cork Oak

By reason of its being native to the Mediterranean region the cork oak, like all natural vegetation, grows in response to the combined effect of the three most essential climatic elements prevailing in that region, namely: temperature, rainfall, and soil. Therefore, each of these elements was studied separately in order to ascertain its function in the distribution and growth of the cork oak.

Temperature is perhaps the most important of all the climatic factors because it influences and regulates every chemical and physical process which is necessary for establishment and survival. We know that there are three cardinal growth temperatures which vary in magnitude depending upon the particular species and variety of plant. There is the minimum temperature below which growth is impossible, the maximum temperature beyond which growth

ceases, and the optimum temperature at which growth is most rapid. The optimum temperature lies somewhere between the minimum and the maximum.

Plants, unlike animals, do not generate their own heat and must, therefore, obtain the heat necessary for their growth and existence from the air surrounding them and from the soil in which they are contained. It is a generally accepted fact that the temperature of plants and plant parts is approximately the same as their surroundings. Temperature, then, is the limiting factor in the growth and distribution of plants, and it determines to a great extent the characteristic flora of the different regions. A good example of a temperature-determined agricultural area is the Cotton Belt of the South which is a region whose mean annual temperature is over 60° F. and whose frostless season is between 180 and 200 days. Another example is the Corn Belt where the mean summer temperature is always above 65° F. and the average night temperature during the 3 summer months is never below 55° F.

Trees in general do not have the characteristic short growing seasons of the agricultural crops and, consequently, their growth is a function of annual rather than specific seasonal temperatures. Consequently, an analysis was made of the mean annual temperatures of the natural cork oak regions with the following results:

The minimum cardinal growth mean annual temperature was found to be 50° F. in regions where the average temperature in January, usually the coldest month, was not below 37° F., which appears to be the limiting temperature of Poleward growth. Since no cork in the Mediterranean region is found beyond these temperature limits, it appeared safe to set the Poleward limit of growth for the potential cork areas of the United States as an imaginary line whose mean annual temperature is not less than 50° F. and whose average January temperature is not below 37° F. Such a limiting line is shown in map II (fig. 2). The region Equatorward of this line constitutes the potential cork area of the United States.

The maximum mean annual temperature at which cork is growing in the Mediterranean region was found to be 70° F.

A complete analysis of the temperature distribution of the natural cork oak is presented in table 2, which shows that the greatest amount (57.2 percent) of cork is growing in the 60°–65° F. region.

TABLE 2.—*Temperature distribution of natural cork oak*

Country	Percent in temperature region of—				Composite temperature (°F.)
	50°–55°	55°–60°	60°–65°	65°–70°	
Portugal	0.9	34.1	65.0	....	60.7
Spain	8.1	67.6	24.3	....	58.3
France and Corsica	....	69.3	30.7	....	59.0
Italy, Sicily, and Sardinia	3.5	39.1	57.4	....	60.2
Algeria	....	4.6	67.9	27.5	63.7
French Morocco	....	....	77.7	22.3	63.6
Spanish Morocco	....	....	100.0	....	62.5
Tunisia	....	....	....	100.0	67.5
Mediterranean region	1.5	27.5	57.2	13.8	61.7

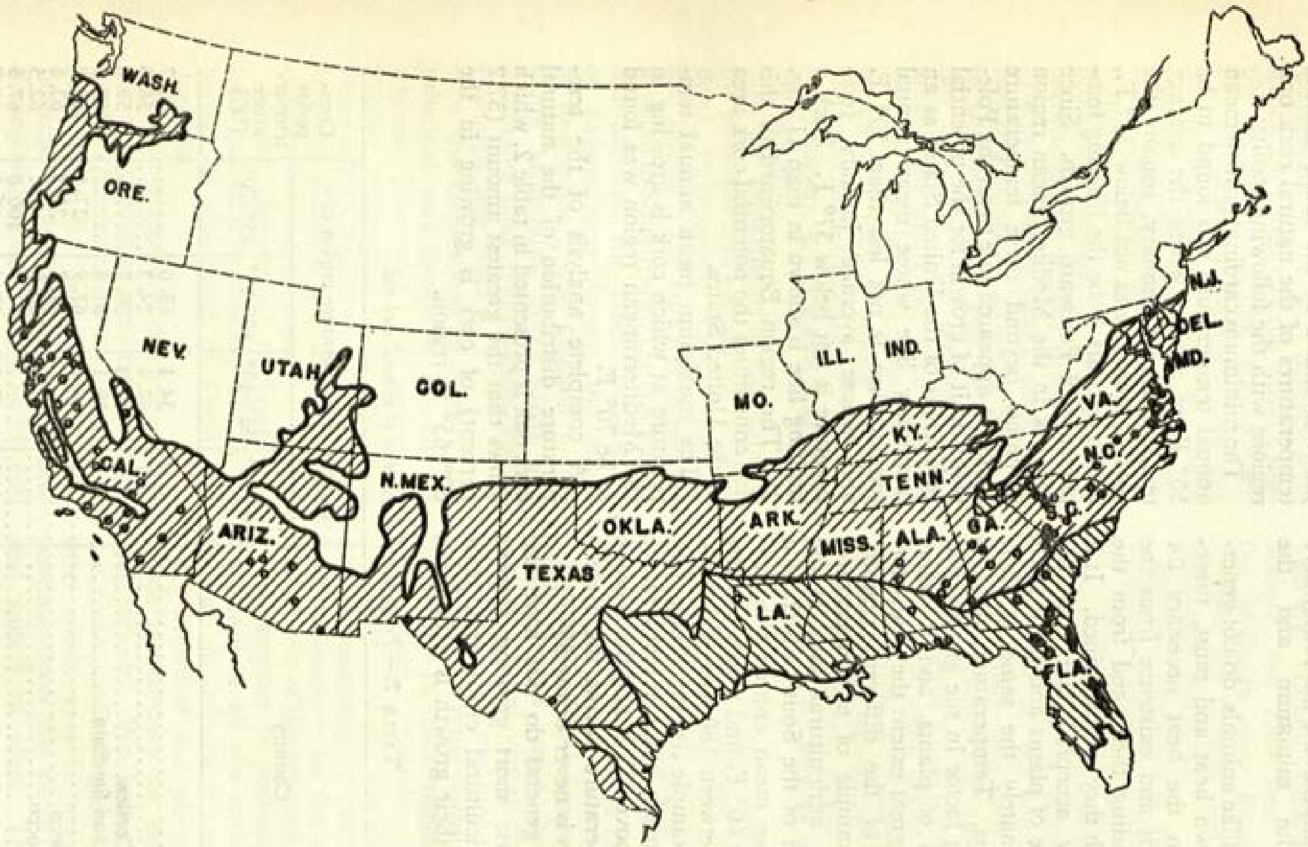

FIGURE 2.—United States. Potential cork areas.

Positive potential area.

Quasi-potential area.

Location of old cork oaks 25 or more years of age. The dots indicate location only; they have no reference to area or to the number of trees.

A study of the temperature regions of the United States shows that no cork trees are growing beyond the established line of the Poleward limit of growth and that both old and young cork oaks are growing between the Mediterranean limits of 50° and 70° F. It is also shown that the United States contains two regions which are hotter than the Mediterranean maximum of 70° F. Although there are no large old cork oaks in either of these regions, numerous young cork trees, planted during the past 7 years, are exhibiting healthy and vigorous growth in the 70°–75° F. region of Texas and Florida and in the 75°–80° F. region of Texas. It is too soon to tell whether or not these young trees are growing more rapidly than others of the same age in cooler regions and, until this fact is determined by later observations, it will not be known whether the optimum cardinal growth temperature has been reached or exceeded. The only known fact seems to be that cork will grow at temperatures between the Mediterranean maximum of 70° F. and the United States maximum of 80° F., thereby indicating that the maximum cardinal growth temperature is above 80° F.

The altitude at which the cork oak grows depends entirely upon the surrounding temperature. It will grow at any elevation where the temperature is above the established minimum growth temperature. The highest cork oak tree on record for the Mediterranean region is the one, shown in plate 7, which is situated at Teniet-el-Had in Algeria and growing at an altitude of 5,280 feet. The highest on record for the United States is the one, shown in plate 8, which is growing at an elevation of 4,520 feet and is situated on the Craig ranch in Superior, Ariz.

When the effect of temperature on the rate of cork growth under constant rainfall in the same soil was studied, the results were as follows:

Mean annual temperature (°F.)	*Rate of growth*
50	0.618
55	.749
60	.908
62.5	1.000
65	1.101
70	1.335
75	1.619
80	1.962

Rainfall (a general term including rain, snow, hail, and sleet) is almost the coequal of temperature in determining the limit of growth of a particular species or variety of plant. Within a given temperature region, the distribution of native plants and agricultural crops depends more upon soil moisture than any other factor.

The amount of available water is usually measured in terms of the depth of rainfall over a specified time. Therefore, the moisture requirements of a given plant can be determined by a study of its distribution in relation to its annual rainfall in inches. In some plants, the season, or time of year, in which the bulk of rainfall occurs is equally as important as the annual quantity, but with trees the seasonal amount appears to be of no particular consequence; the annual depth is the issue of paramount importance. On the annual basis, therefore, a study was made of the rainfall distribution of the Mediterranean cork areas and the result is presented in table 3, which shows that natural cork oak is growing between the mean annual rainfall limits of 10 inches and 60 inches and that the greatest amount (73.5 percent) of cork is growing in the 20- to 40-inch region.

A study of the rainfall regions of the United States shows that there is one rainfall region below the Mediterranean 10-inch minimum and another above the 60-inch maximum. Large old cork oaks are growing in both regions. Cork growth in the region having less than 10 inches of rainfall is chiefly in Arizona. Although much of it is under irrigation, there is a sufficient quantity in the drier parts

TABLE 3.—*Rainfall distribution of natural cork oak*

Country	Percent in rainfall region of—			Composite rainfall (inches)
	10″–20″	20″–40″	40″–60″	
Portugal	22.5	72.9	4.6	27.6
Spain	39.4	59.6	1.0	24.3
France and Corsica	....	95.9	4.1	30.8
Italy, Sicily, and Sardinia	59.2	37.4	3.4	21.8
Algeria	3.4	96.6	....	29.5
French Morocco	56.8	43.2	....	21.5
Spanish Morocco	....	100.0	....	30.0
Tunisia	....	100.0	....	30.0
Mediterranean region	24.3	73.5	2.2	26.8

to indicate healthy growth under less than 10 inches of annual rainfall. In the 60- to 80-inch regions cork is growing along the Pacific coast in northern California and along the Gulf coast in northwestern Florida. The cork trees in these localities are between 30 and 75 years of age, which is sufficient evidence that cork will grow between the Mediterranean maximum of 60 inches and the United States maximum of 80 inches of rainfall.

When the effect of rainfall on the rate of cork growth at constant temperature in the same soil was studied, the results were as follows:

Mean annual rainfall (inches)	Rate of growth
10	0.81
20	.90
30	1.00
40	1.11
60	1.36
80	1.67

Soil is the medium in which all plants grow, and its chemical composition and physical structure depends upon the parent material from which it developed. The parent material, in turn, is largely characteristic of the underlying rock of which it was originally a constituent. Therefore, soils vary considerably in composition, structure, and resultant fertility, depending upon both their lithic and climatic distribution.

The soils of the world have been classified into nine primary groups called the zonal soils. Many similar soils, called intrazonal, are found in all climatic regions; and within the various zonal groups there may be found many different soils on the surface of the primary soil. These comparatively shallow surface soils are important for the growth of crops and grasses. In the case of trees, especially the cork oak with its deep root system and exceptionally long tap root, it is felt that growth is a function of the soil substrata rather than the surface layers. For this reason, a study was made of the Mediterranean distribution of the cork oak in relation to the zonal soils and the result is presented in table 4, which shows that the cork oak is growing in the following primary soil groups, or regions:

Brown steppe soils (or steppe).
Gray-brown forest soils (or forest).
Tropical and subtropical red and yellow soils (or tropical).
Complex soils of mountains and included valleys (or complex).

Table 4 also shows that the greatest amount (84.5 percent) of cork is growing in the brown steppe soil region. These soils are usually in locations of decreased rainfall, or water supply, and are characterized as being semiarid and highly calcareous. In some localities the lime is so concentrated

TABLE 4.—*Soil distribution of natural cork oak*

Country	Percent in soil region of—			
	Steppe	Forest	Tropical	Complex
Portugal	95.7	4.3		
Spain	82.6	1.3	16.1	
France and Corsica		10.5	89.5	
Italy, Sicily, and Sardinia			83.3	16.7
Algeria	100.0			
French Morocco	100.0			
Spanish Morocco	100.0			
Tunisia	100.0			
Mediterranean region	84.5	2.4	12.3	0.8

in the surface that it forms a tough hardpan layer. Despite this fact, the bulk of the world's cork is growing in these types of soils.

The gray-brown forest soils are situated in regions of more abundant rainfall and are considerably more moist than the steppe soils. The forest soils are well adapted to the support of both deciduous and coniferous forests and have been supporting cork oak growth for centuries.

The tropical and subtropical red and yellow soils are on the wetter side of the forest soils and are situated in warm regions of high rainfall. These soils are characteristic of the rainy Tropics and the humid sub-Tropics, such as the "South" of the United States. The tropical soils are well adapted to the support of all types of forest vegetation and have been supporting cork oak growth for hundreds of years.

The complex soils of mountains and included valleys are mixtures of many kinds of soils, intermingled in such a way that no particular type predominates. They are situated in mountainous regions where they receive rainfall in amounts adequate for the support of forest vegetation. Since time immemorial these complex soils have been supporting cork oak growth in the Mediterranean region.

A study of the soil characteristics of the United States potential cork area shows that there are three soil regions in addition to the above-mentioned four Mediterranean groups. They are the desert, chernozem, and prairie soils.

In the potential area of the United States old cork oaks are growing in the desert soils of southern California and Arizona. The greatest numbers of trees are in the regions which are under irrigation and in which the soils are receiving a moisture supply equivalent to approximately 30 inches of annual rainfall. However, there are sufficient numbers in the normal arid regions of low rainfall to confirm the fact that desert soils, as a primary group, are satisfactory mediums for the growth of cork oaks.

The chernozem soils are usually adjacent to, but on the wetter side of, the steppe soils, while the prairie soils are adjacent to, but on the drier side of, the forest soils. Both are situated in regions where the rainfall is ample for crops but not sufficient for the support of forest vegetation. They are considered to be among the most productive agricultural soils in the world. From the point of view of tree growth, however, these soils are less fertile than forest and more fertile than steppe soils.

Although there are no old cork oaks growing in the chernozem and prairie

soils of the United States, there should be no doubt concerning the ability of these soils to support such growth. In the Mediterranean region cork grows in both forest and steppe soils. Forest soil supports tree growth of practically all kinds, while steppe soil is too dry to support natural forest vegetation other than drought-resistant trees like the olive and the cork oak. If both forest and steppe soils support cork oak growth, it stands to reason that the chernozem and prairie soils, which are situated between them with respect to moisture, are satisfactory and may be considered potential soils.

The soils in which the cork oak is growing vary widely in type ranging from the arid desert soils to the moist tropical soils. The range between the respective extremes is so great that it may safely be said that the cork oak shows no preference for any particular type of soil. However, it will not grow in marsh and swamp regions or in soils which are abundantly damp or poorly drained.

The fact that the cork oak prefers no particular soil does not imply that the various types of soils are without effect on the rate of growth. A study of the effect of soils on the growth rate of cork, when temperature and rainfall are constant, gave the following results:

Soil region	*Rate of growth*
Desert	0.95
Steppe	1.00
Chernozem	1.05
Prairie	1.10
Forest	1.15
Complex	1.18
Tropical	1.28

Having completed the study of the independent effects of temperature, rainfall, and soil in relation to the distribution and growth rate of the cork oak, further studies were made on the combined effect of these three climatic elements. Under varying conditions of temperature, rainfall, and soil the composite total rate of growth of cork will be the mathematical product of these three respective rates of growth.

When a single composite, or climatic, environment is taken as a combination of one temperature region, one rainfall region, and one soil region, it is found that cork in the Mediterranean region is growing, under the 27 different environments listed in table 5, at rates between the limits of 0.58 and 1.45.

TABLE 5.—*Climatic environments of natural cork oak*

Temperature region	Rainfall region	Soil region	Composite total rate of growth
50–55	10–20	Steppe	0.58
50–55	10–20	Tropical	.75
50–55	20–40	Steppe	.68
50–55	20–40	Forest	.77
50–55	20–40	Complex	.80
50–55	20–40	Tropical	.87
50–55	40–60	Forest	.94
50–55	40–60	Complex	.99
55–60	10–20	Steppe	.71
55–60	10–20	Tropical	.90
55–60	20–40	Steppe	.82
55–60	20–40	Forest	.93
55–60	20–40	Complex	.97
55–60	20–40	Tropical	1.06
55–60	40–60	Steppe	1.01
55–60	40–60	Forest	1.14
55–60	40–60	Complex	1.20
60–65	10–20	Steppe	.86
60–65	10–20	Tropical	1.10
60–65	20–40	Steppe	1.00
60–65	20–40	Forest	1.15
60–65	20–40	Complex	1.18
60–65	20–40	Tropical	1.28
60–65	40–60	Forest	1.39
60–65	40–60	Complex	1.45
65–70	10–20	Steppe	1.04
65–70	20–40	do	1.21

A similar analysis of the United States potential cork area shows that it contains 38 different climatic environments whose rates of growth lie between the limits of 0.55 and 2.31.

From the data contained in tables 2, 3, and 4, the composite total rate of growth for the Mediterranean region and each of its constituent countries was computed with the results shown in table 6.

TABLE 6.—*Composite total rate of growth of natural cork oak*

Country	Composite rate of growth			
	Temperature	Rainfall	Soil	Total
Portugal	0.9330	0.9759	1.006	0.916
Spain	.8509	.9451	1.047	.842
France and Corsica	.8740	1.0080	1.260	1.110
Italy, Sicily and Sardinia	.9152	.9192	1.260	1.060
Algeria	1.0470	.9952	1.000	1.042
French Morocco	1.0430	.9166	1.000	.956
Spanish Morocco	1.0000	1.0000	1.000	1.000
Tunisia	1.2130	1.0000	1.000	1.213
Mediterranean region	.9696	.9678	1.039	.975

The final results of the climatic analysis show that in the Mediterranean region the cork oak grows: (1) at mean annual surface temperatures between the limits of 50° and 70° F.; (2) under mean annual rainfalls between the limits of 10 and 60 inches; (3) in a variety of soils ranging from the semiarid brown steppe soils to the moist tropical and subtropical red and yellow soils; and (4) at rates between the limits of 0.58 and 1.45.

The Cork Potential

The region within the United States potential cork area, which embraces all four of the above "Mediterranean elements of growth" is graphically presented in figure 2 as the positive potential area. This map also includes an additional region, designated as the quasi-potential area, which is non-Mediterranean in its climatic elements. It is to be noted that old cork oaks are growing in both regions, despite the fact that the quasi-potential area has an average growth rate which is about 30 percent more rapid than the Mediterranean maximum. This is rather definite proof that the cork oak will grow and thrive, within certain limits, beyond the Mediterranean climatic borders, and is sufficient evidence to establish the botanic position of the cork oak tree in this country as being actual rather than potential. Its potentiality lies solely in its economic position with respect to cork production.

The positive potential area is so designated because it is felt that, if the Mediterranean region has been turning out satisfactory cork for over 2,300 years, this positive area, whose climatic elements and growth rates are identically Mediterranean, can be relied upon to produce cork of good commercial quality. This confident feeling is not only further strengthened but is also actually confirmed by the quality of cork obtained in stripping over 500 American trees in the positive potential area. These strippings yielded about 15 tons of mixed virgin and second-growth cork which were sent to the McManus Cork Project in Baltimore for evaluation. The results of physical and chemical tests showed the material to be suitable for making composition cork products, insulation blocks, and commonplace articles. It was found to be comparable in all respects with Mediterranean cork of similar character and grade.

No stripping has been done in the quasi-potential area, but specimens have been sporadically cut from a limited number of trees and, in all instances, the cork has been found to

be of inferior quality to that in the positive area. It did not compare favorably with the poorest grades of Mediterranean virgin growth. This rather strongly indicates that the quality of cork decreases as the rate of growth increases and that commercial grades are not obtainable from regions in which the rate of growth exceeds the Mediterranean maximum limit. Therefore, in the United States, the growth of cork for a national economy should be restricted to the positive potential areas.

All the cork coming from the Mediterranean region is not of equal quality; it varies considerably with location. Only part of it can be used for the highest type of manufacture, such as champagne and wine corks and composition cork liners for food and beverage closures, while the bulk is employed in the production of thermal insulation, compositions, and miscellaneous articles. The finest-textured and highest-quality cork comes from Spain and Portugal which, as is shown in table 6, have the slowest rates of growth in the Mediterranean region, namely 0.842 and 0.916, respectively. From this it appears reasonable to infer that cork quality is a reciprocal function of the rate of growth.

If rapid growth, especially that in excess of the Mediterranean maximum, is detrimental to the commercial quality of cork, the quasi-potential area should be limited to the planting and growing of the cork oak tree for its architectural and ornamental beauty, its soil conservation properties and, particularly, its acorn crops. Therefore, what the quasi-potential area loses in cork production is offset by what it gains in landscaping and hog-raising potentialities. Much of the barren and uncultivated lands in this area can be planted to cork oaks and transformed into parklike groves in which hogs can feed on the acorn crops and ultimately produce pork at the estimated rate of 30 to 40 pounds per acre per year.

The geographic distribution of the positive and quasi-potential areas is also shown in figure 2. A study of this map shows that there are 27 States in the United States potential cork area. Eighteen contain positive areas only; they are: Arizona, California, Colorado, Delaware, Illinois, Indiana, Kentucky, Maryland, Missouri, Nevada, New Jersey, New Mexico, Oklahoma, Oregon, Tennessee, Utah, Virginia, and Washington. The following seven States contain both positive and quasi areas: Alabama, Arkansas, Georgia, Mississippi, North Carolina, South Carolina, and Texas. The remaining two, Florida and Louisiana, are wholly quasi-potential.

The positive potential area presents itself as the most suitable location in which to build the Nation's cork-forest industry, because it is identical to the Mediterranean region in climatic elements and growth rate. It embraces an area of 888,050 square miles. If over 90 percent of this area is already occupied by cities, towns, roads, farms, pastures, woodlands, and other uses, there would still be more land available than is needed to produce this country's requirement of 160,000 tons of cork annually. It will be shown that no more than 1,000,000 acres (1,562.5 square miles) will be needed to produce cork at this rate.

In order to obtain a fair estimate of what might reasonably be expected of the tree with respect to its production of cork, it is necessary to study separately each factor that produces a quantitative effect on the yield. Having done this, it becomes apparent that cork production is a function of the combined effect of several contributing factors.

The amount of cork which a tree will produce over a given period of time depends upon the rate of growth of its immediate environment and upon the regularity with which stripping operations are performed. After the removal of the first (or virgin) growth, a second growth begins within a very few months and progresses at

a rate faster than the initial growth. After the second stripping, a third growth progresses at a rate faster than the second. This apparent stimulation repeats itself after each successive stripping. The phenomenon of stimulation in relation to quantitative yield was carefully studied during the 6-year period of stripping. As a result of this work it has been possible to estimate, with a reasonable degree of accuracy, the cork yield per tree at various ages up to 100 years. Although the life of a cork tree in the Mediterranean region ranges from 150 to 200 years, or slightly over, we did not feel justified in carrying the estimation to the limit because we did not have the fundamental data to support it. The estimate, shown in table 7, is based upon the results of stripping trees between the ages of 20 and 90 years.

TABLE 7.—*Relation between annual cork yield per tree and age in the United States potential cork area*

	Potential area	
	Positive	Quasi
Mean rate of growth...	0.9667	1.8439
Pounds per annum per tree at:		
10 years..........	.00	.00
20 years..........	1.59	3.65
30 years..........	2.83	6.50
40 years..........	5.04	11.55
50 years..........	8.96	20.54
60 years..........	15.93	36.54
70 years..........	28.32	64.97
80 years..........	50.39	115.50
90 years..........	89.60	205.40
100 years.........	159.30	365.40

It is felt that the estimate is fairly representative of average production conditions and that it is sufficiently accurate for the practical purposes of comparison and estimation.

In addition to the rate of growth and stripping regularity, the amount of cork produced by a given tree is greatly influenced by the shape of its various parts, such as trunk, branches, crotch, etc. During the stripping of over 500 trees of all shapes, sizes, and ages, it was determined that the shape of an individual tree may cause it to deviate as much as 21 percent from the average values in table 7. However, when a number of trees of different shapes are averaged, the cork yield per tree agrees very closely with the estimate.

In order to determine, for commercial reasons, the cork yield per acre, or any other unit, it is necessary to know the number of trees an acre will accommodate. Mediterranean experience has shown that cork yield is at its maximum, quality at its highest, and fruiting (acorn production) at its best when the trees are widely spaced so that they grow in full light without crowding or touching. Therefore, as the trees grow and their crowns spread, the acreage must be systematically thinned in order to give each tree room for free, unhampered growth. The rate at which the crown spreads, or increases in diameter, depends upon the rate of growth of the region in which the tree is located; and the number of trees which an acre will accommodate depends upon the diameter of the crown.

Since the first and second strippings are of no real commercial value and the cork oak is not considered to be commercially mature until it is 40 years of age and has yielded its third stripping, there is no point in planting more trees originally than an acre will accommodate at 40 years of age. On this basis, in conjunction with the variations in crown spread with growth rate and age, the number of trees per acre in relation to age was computed with the results presented in table 8, wherein it is seen that, for the first 40 years, the number of trees per acre is constant and, after 40 years, the number is variable, decreasing by thinning as the age increases.

TABLE 8.—*Relation between the number of trees per acre and age in the United States potential cork area*

	Potential area	
	Positive	Quasi
Mean rate of growth...	0.9667	1.8439
Trees per acre at:		
Initial planting.......	43.53	8.85
40 years..............	43.53	8.85
50 years..............	29.97	6.09
60 years..............	22.11	4.49
70 years..............	17.09	3.47
80 years..............	13.68	2.78
90 years..............	11.23	2.28
100 years............	9.43	1.91

The cork yield per acre per annum at any given age may now be determined by multiplying the yield per tree per annum (table 7) by the number of trees per acre (table 8) with the results shown in table 9.

TABLE 9.—*Relation between annual cork yield per acre and age in the United States potential cork area*

	Potential area	
	Positive	Quasi
Mean rate of growth.	0.9667	1.8439
Pounds per annum per acre at:		
10 years........	.00	.00
20 years........	69.21	32.30
30 years........	122.89	57.52
40 years........	219.39	102.22
50 years........	268.53	125.09
60 years........	352.21	164.06
70 years........	483.99	225.45
80 years........	689.34	321.10
90 years........	1006.21	468.31
100 years.......	1502.20	697.91

A marked peculiarity shown in table 9 is the fact that, at a given rate of growth, the cork yield per acre increases with age but, at any given age, the yield decreases as the mean rate of growth increases. In other words, the region in which the cork tree grows the fastest produces the least amount of cork per acre. This phenomenon is readily explained by the fact that the number of trees per acre (table 8) decreases at a faster rate than the cork yield per tree (table 7) increases. The net result of this situation is nothing to cause undue alarm. It is not only a perfectly normal condition, but it is also a typical Mediterranean characteristic. Table 6 shows that Spain has the lowest rate of growth (0.842) in the Mediterranean region, while, in table 1, it is shown to have the highest cork yield per acre (212 pounds).

This evidence considerably strengthens the argument in favor of limiting the growth of commercial cork to the positive potential area which is the only region in the United States with climatic environments and growth rates identical with those of the Mediterranean region. This does not mean that the quasi-potential area is to be neglected. In addition to its hog-raising possibilities, this area can render a valuable service to the Nation by planting to cork trees the vast amount of lands which it contains that are now out of agricultural production due to the depleted condition of their soils. Since the scarcity of food-producing land is a problem not only in the United States but all over the world, any land that has food-producing potentiality should not be planted to cork oaks.

The Cork Forest

The most desirable cork-forest industry for the United States is one which will produce sufficient cork to meet our yearly requirement of approximately 160,000 tons. A forest which will produce at this rate must, as will be shown, contain at least 28,000,000 trees planted on almost 1,000,000 acres. Such a planting, however, could not be made in any one year because the acorns are not available. It would require 84,000,000 acorns, since common practice is to plant three acorns to a hill in order to assure the germination of one.

At present, about 1,200,000 acorns are being collected yearly from approximately 1,000 California trees. This permits planting for 400,000 trees per year. At this rate, it would require 70 years to plant the forest. But, there are upward of 4,000 trees in California. Therefore, there is no reason why collecting cannot be organized along progressive lines so that the entire acorn crop of over 4,000 trees becomes available within a period of 20 years.

A national forest could be started with a moderate beginning of 240,000 trees the first year which would be increased progressively each year by a common difference of 80,000 trees. For example, 320,000 trees would be planted the second year, 400,000 in the third year, and so on, for 20 consecutive years. At the end of 20 years, 20,000,000 trees will have been planted. This will utilize the full acorn capacity of California's old trees. Beginning with the twenty-first year, however, the first planting will have reached full fruiting maturity and its acorn crop can be added to that of California's. Each succeeding year an additional larger planting will mature so that planting can be stepped up to the rate of 3,200,000 trees for the twenty-first year and 4,800,000 for the twenty-second year. At the end of 22 consecutive years of progression planting, 28,000,000 trees will have been planted, which is the number estimated to fulfill the country's requirements.

In such a progressively planted forest as that suggested above, its age at any time after the first year is composite and its cork yield is cumulative. Therefore, different methods had to be used to estimate the forest yield than those employed for the yield per acre when all trees were of the same age. After developing the proper mathematical procedure for determining the yield of a progressively planted forest, studies were made on the basis of planting for 20, 22, and 25 consecutive years. It was shown that the progressively planted forest would not clear itself of first and second growths of cork and produce 100 percent of the commercial grades of third and after strippings until the sixtieth year in the case of planting on the 20-year basis, and the seventieth year for the remaining plantings.

It was also determined that on the 20-year basis of planting about 95 years would be required for production to meet the country's requirement of 160,000 tons annually. This is entirely too long a period to wait for our cork independence. On the other hand, the 25-year basis of planting will meet the 160,000 tons per annum requirement in the fifty-seventh year but, with reproduction at the rate of table 7, the yield of cork would be too great for its own commercial good. At the end of 100 years, the supply would be so far in excess of the demand that cork would inevitably become an economic "bauble."

The 22-year planting, with 28,000,000 trees on 916,264 acres, presents itself as the most economical basis on which to build the Nation's cork-forest industry. The production rate of such a forest is presented in table 10 which shows that the country's requirement

TABLE 10.—*Estimated rate of "stripped" production for the 22-year forest planted with 28,000,000 trees on 916,264 acres in the positive potential cork area of the United States*

Age in years	Yield in short tons per annum for stripping of—		
	First (virgin)	Second	Third and after (commercial)
20	220		
30	7,053	390	
40	25,065	11,860	694
50	18,619	30,579	15,316
60		24,391	60,391
70			116,269
80			165,477
90			241,710
100			360,367

of 160,000 tons per annum will be met in the seventy-ninth year, and, at the end of 100 years, the output will about equal the present production of the Mediterranean region, which is in the neighborhood of 350,000 tons per annum. The yield of this so-called 22-year forest is well within the bounds of good economy and is adequate for the Nation's need in times of peace and war.

These 28,000,000 trees should be proportionately planted by States in relation to their respective positive potential areas. A suggested plan of planting is presented in table 11.

TABLE 11.—*Total number of trees after planting for 22 consecutive years*

State	Number of trees in positive potential area
Alabama	551, 432
Arizona	5, 141, 360
Arkansas	755, 272
California	4, 979, 688
Colorado	160, 272
Delaware	51, 744
Georgia	553, 840
Illinois	149, 016
Indiana	60, 368
Kentucky	691, 544
Maryland	137, 984
Mississippi	349, 160
Missouri	247, 324
Nevada	400, 680
New Jersey	34, 496
New Mexico	3, 950, 464
North Carolina	763, 896
Oklahoma	1, 171, 688
Oregon	749, 224
South Carolina	373, 240
Tennessee	807, 044
Texas	3, 815, 140
Utah	1, 095, 192
Virginia	578, 116
Washington	431, 816
United States positive potential area	28, 000, 000

NOTE: The number of trees which each State must plant the first year is 3/350th's of the corresponding numbers in the above table.

SOME ESSENTIAL FACTORS

Having virtually established the location of the forest, attention can be concentrated upon proper plans for the collection and distribution of acorns, suitable processes for stripping the trees without loss, and correct methods for the management of the many cork oak plantations which will be scattered throughout the 25 States in the positive potential area. At the same time, exhaustive studies must be made of growth phenomena in order to establish, for future use, the propagation requirements of the cork oak tree in this country. Organized stripping research must be continued and elaborated upon, so that additional fundamental data may be accumulated on the relation between cork reproduction and age, and between cork quality and growth rate. These tasks of planning, study, and research are the present functions of the McManus Cork Project and its cooperating members. The ultimate aim of the project is to firmly establish the essential foundations for a cork-forest industry in the United States.

In the national cork project, the State of California occupies the key position because it contains most of the worth-while acorn-bearing trees in the country and, consequently, all the raw material needed to build the proposed industry. During the first 20 years, California must furnish at least 60,000,000 acorns to permit the planting of 20,000,000 trees, and, at the same time, must function as the experimental laboratory in which hundreds of plantation workers from other States can observe and learn the correct procedures for stripping and harvesting cork in order that operators may realize a profitable return on their investment in land and labor.

Usually the choice of a specific crop for a given piece of land is based upon comparison of its economic factors and financial returns with other crops adapted to the same land. The cork oak tree will not be in competition with agricultural crops because it is not to be planted on land which has food-producing potentiality. It is competitive only with such tree, grass, and other crops as are adapted to marginal lands and to soils that are nonproductive in the agricultural sense.

It is only on these types of lands that the cork oak is to be grown. Under such circumstances it is felt that cork will compare favorably with competitive crops.

In order to give the potential planter an idea of what to expect in the way of a return on his investment, an analysis of the present-day market prices of Mediterranean cork was made and the result is presented as an average value, subject, of course, to reasonable commercial deviations. The average value will serve as a basis of comparison in determining the feasibility of growing cork as a crop.

The total Mediterranean production is comprised, on the average, of 35 percent of corkwood, or bark, and 65 percent of waste, strippings, shavings, and refuse. Both the corkwood and the waste are supplied in many different grades. There are about 32 different grades of corkwood covering the virgin, second, third, and after strippings. Grading is based upon thickness and quality. The waste, etc., derived from cutting, trimming, and processing the above grades of corkwood is classified into some 12 different grades.

The present price of corkwood, f. o. b. the Mediterranean region port of shipment, ranges between $84.59 per short ton for the virgin growth and $519.25 for the highest-quality, thickest, and finest-textured grade. The composite price of all grades, based upon proportionate production, is $134.42 per short ton. The derived waste runs from $38.18 for the lowest grade of refuse to $92.73 for the highest grade of selected strippings. The composite price of the waste cork is $77.05 per short ton. Therefore, on the basis of 35 percent cork wood and 65 percent waste, the present composite price of Mediterranean cork would be $97.13 per short ton.

The American manufacturer must add to the above unit prices approximately $38.19 to cover the cost of buyer's fees, ocean freight, insurance, and land freight on this side. Cork that is grown in the United States will also have its transportation charges, which will vary with respect to forest location in relation to the point of ultimate consumption. The bulk of cork in this country is consumed on the Atlantic seaboard, and, since it will be grown from the Atlantic to the Pacific coast, freight charges ranging from $5 to about $40 per short ton must be taken into consideration. Based upon the proportionate planting of each State in the positive potential area, the composite cost of freight and transportation will be $22.59 per ton. This represents an average saving of $15.60 per ton over the Mediterranean freight cost which must be passed on to the user as his incentive to buy American-grown cork. Therefore, the American planter can, at all times, sell his cork at the prevailing Mediterranean region prices.

With $97.13 per ton as the current composite price of all grades of cork, the annual income per acre for the 22-year forest of table 10 would be at the rate shown in table 12.

TABLE 12.—*Rate of annual income for the 22-year forest with the composite price of cork at $97.13 per ton*

At end of year	Annual dollar income per acre	At end of year	Annual dollar income per acre
10	0.00	60	8.98
20	.03	70	12.33
30	.80	80	17.54
40	3.99	90	25.62
50	6.84	100	38.20

At the end of 100 years, the average income for the entire period will have been at the rate of $11.43 per acre per annum. It is interesting to compare this rate with that of the Mediterranean region which has been producing for hundreds of year. Table 1 shows the annual cork yield for the Mediterranean region to be 112 pounds (0.056 ton) per acre. With

cork at $97.13 per ton, this is equivalent to an annual income of $5.44 per acre, which is about one-half that of an estimated acre in the United States. From the investment point of view, it appears that the cork oak in this country will compare very favorably with that in the Mediterranean region.

The cork forest produces income in addition to that derived from the cork. For the first 20 years, while the trees are young, the land provides forage for sheep, goats, and other cattle. When the acorns mature in the twentieth year, the land may be converted to hog pasture, and used as such throughout the life of the forest, so that cork and pork will be produced at the same time. After the fortieth year, thinning provides wood from which additional income may be derived. These augmentative commodities will probably more than offset the cost of rent, labor, and overhead, so that the return on the cork will be all profit.

Cork production will remain profitable only as long as an economic balance is maintained between supply and demand. Any tendency to overproduce will invariably prove to be detrimental to the undertaking. Therefore, if the proposed cork-forest industry is to be within economic bounds, the total number of trees should not exceed the 28,000,000 prescribed in the 22-year forest of table 10.

It would be purely conjectural to attempt a statement as to how long and at what rate the 22-year forest will continue to produce. These are essential points which must be determined by observation and study of growth and production trends during the earlier stages of development, in order that reliable data might be obtained concerning the cycles in which subsequent forests should be planted so that they arrive at maturity when the preceding one reaches exhaustion, and, thereby, perpetuate cork production at a rate that will satisfy the Nation's need.

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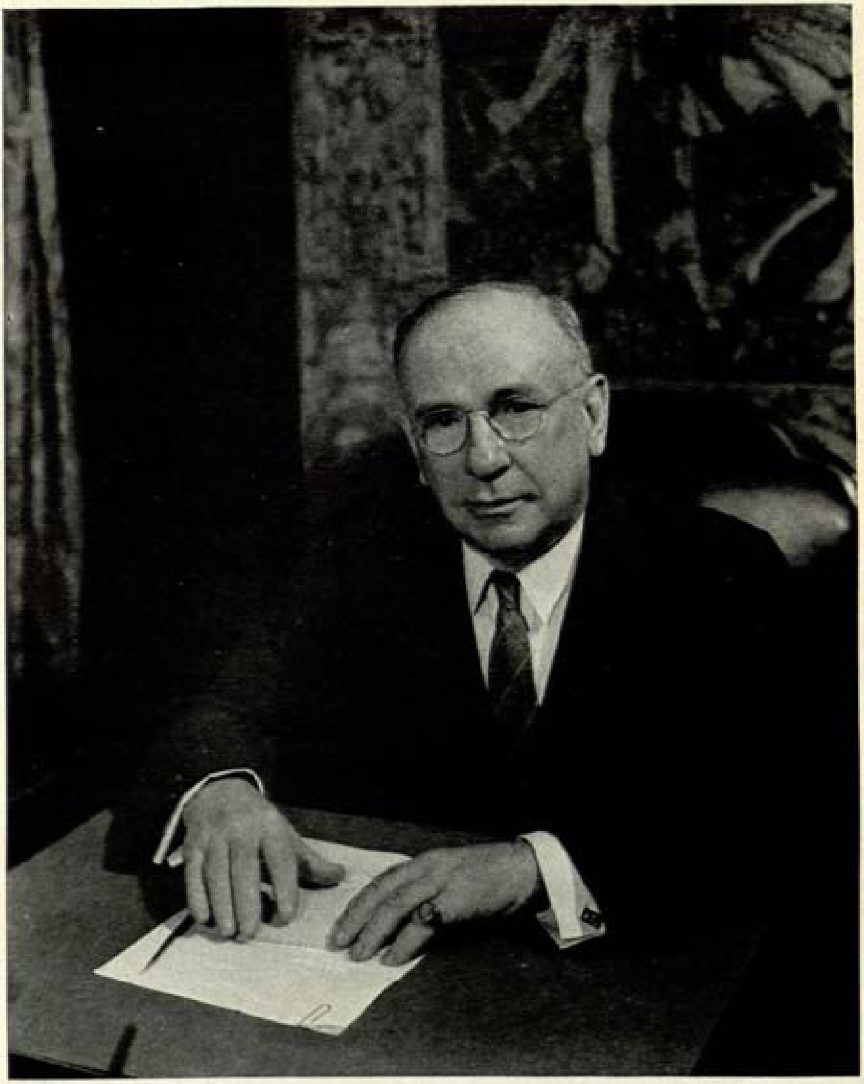


CHARLES E. MCMANUS, 1881–1946

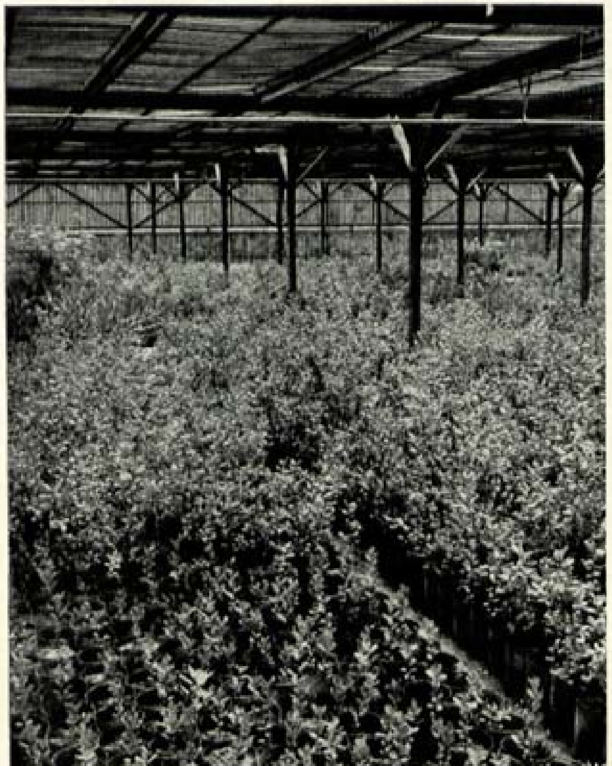
Former president and chairman of the board of the Crown Cork and Seal Company, Inc., who initiated the present cork-growing program in the United States and established the McManus Cork Project.

1. THE LARGEST GROVE OF MATURE CORK OAK TREES IN THE UNITED STATES, CHICO, CALIF.

These trees supply many acorns every year for additional plantings.

2. A TRUCKLOAD OF ACORNS OF THE CORK OAK

Hundreds of thousands of cork acorns like these are collected and distributed annually throughout the warmer half of the United States.



1. CORK OAK SEEDLINGS IN INDIVIDUAL CONTAINERS, READY FOR PLANTING

2. HON. JIM McCORD, GOVERNOR OF TENNESSEE, PLANTING A CORK TREE ON THE STATE CAPITOL GROUNDS AT NASHVILLE, MARCH 5, 1948

1. YOUNG CORK TREE, COLLEGE STATION, TEX., JUNE 1948

Diameter, breast high, 3.1 inches; height, 10.9 feet. From acorn planted in 1943. Photograph courtesy Texas Forest Service.

2. YOUNG CORK TREE, HASTINGS, FLA., DECEMBER 1947

Diameter, 3 feet from ground, 2.5 inches; height, 13.5 feet. From seedling planted in 1942.

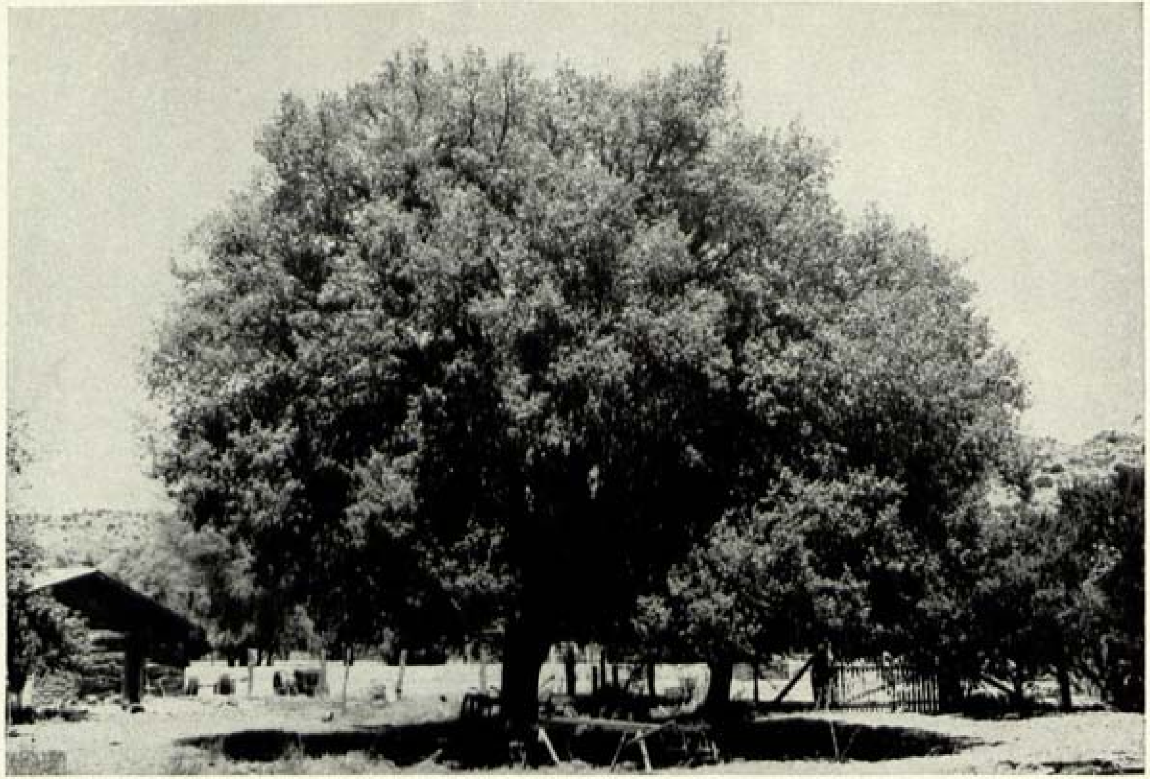
STRIPPING VIRGIN CORK FROM A LARGE TREE IN MERCED COUNTY, CALIF., AUGUST 1943

SECOND-GROWTH CORK BEING REMOVED FROM A CORK TREE AT DAVIS, CALIF., JULY 1948

The virgin cork was stripped from this tree in 1942.

CORK OAK GROWING AT AN ALTITUDE OF 5,280 FEET AT TENIET-EL-HAD IN ALGERIA

The trunk has recently been stripped. Note the thick virgin cork on the large branches.



CORK TREE ON CRAIG RANCH, SUPERIOR, ARIZ., PLANTED IN 1879

Many times it has been subjected to temperatures of zero in winter and 120° in summer. Elevation, 4,520 feet.

Remember the Chestnut![1]

By Amanda Ulm

[With 4 plates]

During the summer of 1904, a number of American chestnut trees in New York City's Zoological Park withered and died. Many attributed the loss to the unusually cold winter of 1903, but Herman Merkel, the park's chief forester, suspected something more. He sprayed the trees with a fungicide and reported his observations to the United States Department of Agriculture in Washington. No one became alarmed, however. Chestnuts were plentiful in the woods about the city and there was no evidence of anything wrong outside the Zoological Park.

Yet within 7 years it was difficult to find an unblighted American chestnut in the Empire State, and by 1940 healthy specimens of this great tree had virtually disappeared from the woodlands of the East. Only in certain sections of Mississippi and Tennessee were unblighted trees still reported.

To the present generation of young Americans the disappearance of the chestnut from the eastern woodlands is little more than a chapter of history. And to their great misfortune they have been deprived of an association that is still deeply etched in the memory of many of their elders. Henry David Thoreau undoubtedly spoke the minds of many when he wrote of this magnificent tree:

> When chestnuts were ripe I laid up half a bushel for winter. It was very exciting at that season to roam the then boundless chestnut woods . . . with a bag on my shoulder, and a stick to open burs with in my hand . . . amid the rustling of leaves and the loud reproofs of the red squirrels and the jays, whose half-consumed nuts I sometimes stole. . . . Occasionally I climbed and shook the trees. They grew also behind my house, and one large tree which almost overshadowed it was, when in flower, a bouquet which scented the whole neighborhood, but the squirrels and jays got most of its fruit. . . . I relinquished these trees to them and visited the more distant woods composed wholly of chestnut.

Yet the story of the chestnut is one every American should know and ponder. For not only is it a tragic reminder of what can happen to a valuable resource when danger signals are ignored, but it points with millions of dead and ghostly snags, all that is left of one of the most magnificent trees indigenous to our woodlands, to the fallacy of the kind of thinking that adds up to "too little, and too late." And unless the American people show greater understanding of the destructive power of tree-killing diseases and insects, the tragedy of the chestnut can be re-enacted. The present plight of the American elm is eloquent testimony to this.

The chestnut, of course, was more than a sentimental loss to the Nation. A superbly beautiful tree, often towering 100 feet or more in the forest, it was of high commercial value, an important part of the Nation's economy. Its wood was durable and rot-resistant, ideal for telephone poles, shipmasts, and railroad ties. Great quantities were used for interior wood-

[1] Reprinted by permission from American Forests, April 1948.

work. And as a source of tannic acid it was unsurpassed. Indeed, by the time the blight had moved from New York to Virginia, it was estimated that the loss in timber alone was in excess of $25,000,000.

The tragic part about our attitude toward destructive diseases and insects is that, because they work silently and undramatically, we find it difficult to become greatly concerned until their deadly work is done. Then we lick our wounds, total up our losses, and indignantly ask each other, "Couldn't it have been prevented?"

We are still asking this about the chestnut disaster. The answer, however, is likely to be lost somewhere in this pattern of reasoning: at the time of the outbreak there was little understanding of plant diseases; much valuable time was lost after the outbreak in searching out the factors responsible for the epidemic and in vacillation and acrimonious debate; the disease, once established, spread like lightning; and finally the eastern woodlands became so thoroughly permeated that no human control was practical.

When Forester Merkel examined the trees dying in New York's Zoological Park, he found interesting marks on their trunks and branches. A sunken area of dried-out bark, a sort of canker, was always present. On the surface of the cankers he frequently saw thousands of yellowish pin-point projections. He immediately sent samples of this material to the Department of Agriculture, which reported that the bark was riddled with a fungus, that the yellow pin points were fruiting bodies, containing millions of spores. When these spores were released from the fruiting bodies they could be blown miles to infect other chestnut trees.

This particular fungus was a deadly parasite. Only one infinitesimal spore lodged in a fissure or slight abrasion of the protective bark of the chestnut could send out minute rows of rootlike strands which would expand into a fan-shaped, white or buff-colored mass. The "fan" would penetrate the trunk of the tree, pushing its way into the sapwood. Eventually, the fungus would destroy the cells growing next to the tubular conductors through which water ascends from the tree's roots to its leaves, thus cutting off the tree's water supply. The net result of this interior strangulation was identical with the effect of girdling a tree trunk with knife or ax.

Despite these revelations regarding the disease, protective action was ineffective. Merkel's attempt to control the spread of the fungus with Bordeaux, a copper-sulfate spray which the French had used successfully in controlling a fungus disease of grape, was a complete failure. So, with nothing to block its progress, the blight, by 1911, had spread from New York to New Hampshire, Connecticut, New Jersey, Pennsylvania, West Virginia, and Virginia.

A number of scientists believed the disease would disappear of its own accord, but generally there was rising fear that it would sweep down through the extensive chestnut forests of the South. One of the first real stands made against its march was in Pennsylvania where a Chestnut Tree Blight Commission was created with $275,000 at its disposal. Believing the blight controllable, the commission set about making investigations of practical control measures, started research on the peculiarities of the blight fungus, and dispatched 200 scouts to locate and destroy infected trees. Its peak effort was a serious, if not desperate, attempt to establish a 10-mile zone across which, it was hoped, the blight organism would fail to find its way. Within this "immune belt," as it was called, all chestnuts, healthy and diseased, were destroyed.

Previous investigation of the blight fungus revealed that instead of one type of spore, as supposed, the fungus possessed two types. The first, called *ascospore* by the researchers, was produced in microscopic receptacles with-

in the pin-point pustules. Extremely small, it was easily blown by the wind to infect new trees. The second was contained in sticky yellow ribbons extruded from the pustules more or less as toothpaste is extruded from a tube. These were called *pycnospores.* Being moist, they adhered to the feet and bodies of wild animals, and were thus carried considerable distances to other chestnut trees.

This apparent ability of the blight fungus to spread under any conditions played right into the hands of opponents of the "immune belt" theory, who could see no purpose in putting thousands of dollars into what they believed was a lost cause. The result was that 2 years later the Chestnut Tree Blight Commission ceased control work. Hastening its demise was the failure of a number of other States to cooperate. Later experience has shown that the blight can be kept out of certain localities, and there is reason to believe that elimination of trees in advance of the main progress of the fungus in Pennsylvania deterred the blight by at least 5 years.

From 1913 on, with practically no human opposition, the blight spores continued to be carried southward and westward.

The severity of the disease made it clear to most investigators that this was no mere flare-up of an indigenous parasite, though a few maintained the pathogen to be a curious mutation of a heretofore harmless fungus. Others believed it had come from European trees imported to this country. In the 80's and 90's of the last century there had been a great wave of interest in commercial chestnut orchards, and large numbers of chestnut trees were brought in from Europe by nurserymen.

When a fungus, claimed by a number of experts to be identical with the organism causing blight on our native trees, was found on these European chestnuts, the mystery appeared solved. The reasoning was that this fungus, termed *Endothia radicalis,* though apparently harmless to the European chestnut, was deadly to ours. This plausible hypothesis, however, was exploded when it was shown that the European tree, when attacked in this country by the fungus from one of our blighted native chestnuts, also withered and died. Eventually, the two fungi were found to be different, though related. The blight-causing fungus, *Endothia parasitica,* was virulent and definitely fatal in effect. The other was innocuous and attacked only dead tissue.

With Europe eliminated as a source of blight, scientists began to look elsewhere, notably to the Asiatic countries. They began with the Japanese chestnut trees that had been brought into this country in the latter part of the nineteenth century, and it was soon observed that some contained cankers indicating infection from blight. The Japanese tree often survived, however. It was this resistance that gave investigators Haven Metcalf and C. L. Shear the clue they were looking for. Both scientists had become convinced the blight had entered this country from the Orient—but they needed proof.

Dr. Shear's first act was to send a specimen of diseased chestnut bark to Frank Meyer, the famous plant explorer, then in China, who agreed to search for comparative evidence of blight in that country.

The American researchers did not have long to wait. Within a short time Meyer wired that he had found evidence of what he believed to be blight. Three weeks later the Department of Agriculture received a specimen of bark from a Chinese chestnut which Meyer had located in northern China. Metcalf immediately examined the material and reported, "It looks like it." Then Shear found the characteristic *ascospores* in cultures made from the bark. Later the scientist inoculated trees in this country.

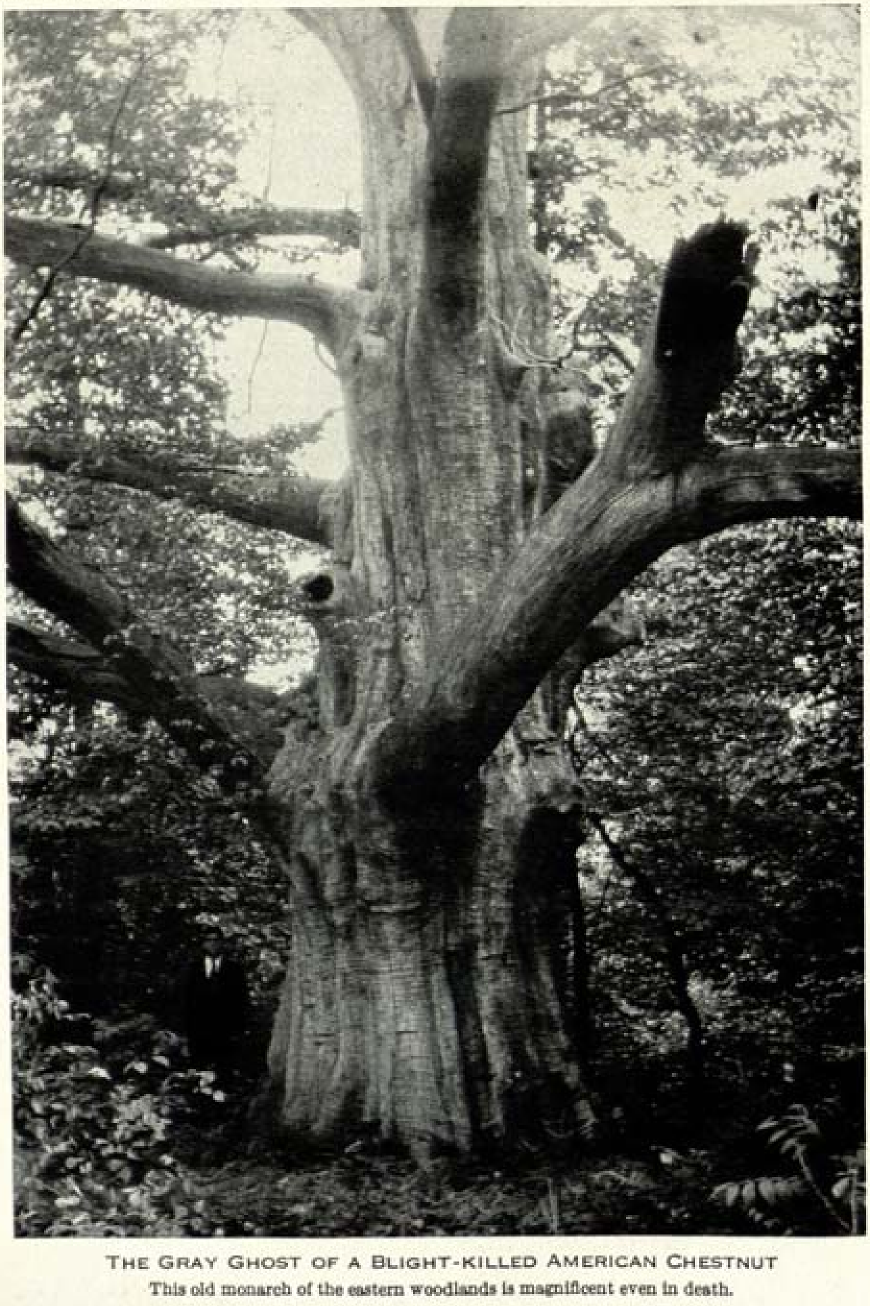
Thus, in less than 3 months, it was definitely established that the chestnut

Udine. Until the war, control measures were enforced. Quarantine of the infected localities and destruction of diseased trees were exactingly carried out.

Now the blight has full sway. War and the consequences of war have made it impossible to organize the control necessary to check it.

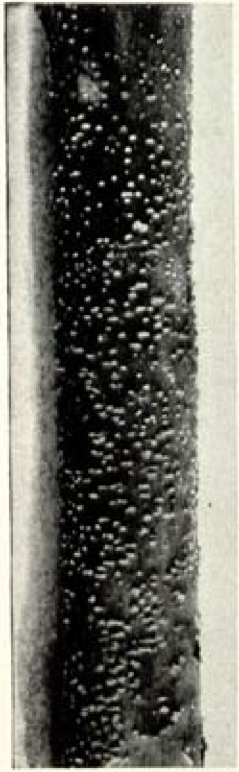
There is an old Indian myth which tells the story of an Iroquois boy who braved the perils of a deep chasm in the earth, wild animals, a serpent, and a woman whose single penetrating glance would kill, to find magic chestnuts. He brought back a bagful of the precious nuts and, going up on the side hills, scattered them over the ground. Soon beautiful chestnut trees grew up and, the story concludes, "now all the world has chestnuts." This is no longer true, but perhaps if our plant breeders can brave the perils of governmental economy we may some day give resistant chestnuts to all the world.

NATIVE AMERICAN CHESTNUT BEFORE BLIGHT, HOWARD COUNTY, MD.



THE GRAY GHOST OF A BLIGHT-KILLED AMERICAN CHESTNUT

This old monarch of the eastern woodlands is magnificent even in death.



1. BLIGHT PUSTULES WHICH PRODUCED SPORES EASILY BLOWN BY THE WIND

2. RIBBONLIKE SPORES WHICH ADHERED TO THE FEET OF ANIMALS AND WERE THUS SPREAD

3. "FAN" OF BLIGHT FUNGUS WHICH KILLED TREE BY CUTTING OFF WATER SUPPLY

HYBRIDS

Selected Chinese chestnuts crossed with native chestnuts have produced blight-resistant trees.

The Numbers and Distribution of Mankind[1]

By C. B. Fawcett

The problems presented by the distribution of the human population over the surface of the land, and its relations to the natural resources of the earth, form the principal subject-matter of human geography.[2] Our knowledge of these matters is still very inadequate. There are wide margins of error in the available statistical material,[3] and still wider gaps in our knowledge of the earth's resources. Yet it seems worth while to attempt to set out some of the facts bearing on these problems as fully as possible.

In this address I shall attempt to consider briefly only three of the groups of factors in these problems:

(1) That of the actual magnitude of the present human population, and the main features of its distribution over the land surface.

(2) The relation between the distribution of the population and that of the fertile lands from which the food of mankind is obtained.

(3) On the basis of the first two factors I have ventured to estimate the population capacity of the world on some existing standards of production and consumption.

Numbers

The first question is "How many people are there in the world today?" It is not possible to answer this question exactly. In most of the lands of Western civilization, and in many other lands under their control, fairly reliable censuses[4] have been taken. So we can state the numbers of the inhabitants of Europe and North America, of the countries of the South Temperate Zone, and of Japan and India, with some approach to accuracy. But for the large population of China, and for the intertropical lands of the Americas and Africa we have only estimates of very varied value. Some of these estimates are based on partial censuses, some are hardly more than guesswork.

Thus there is necessarily a wide margin of error in all estimates of the world's population, which should be remembered in studying the following figures.

[1] British American Association Lecture delivered at the Annual Meeting of the American Association for the Advancement of Science, in Boston, December 1946. Reprinted by permission from The Advancement of Science, vol. 4, No. 14, June 1947 (London).

[2] E. g., Part I of F. Ratzel's Anthropogéographie is given to this topic; so also is Part I of P. Vidal de la Blache's Principes de Géographie humaine.

[3] Because of these difficulties all the figures used in these calculations are round numbers; none of the resulting estimates should be regarded as more than first approximations. Cf. the general note on p. 13 of the Statistical Yearbook of the League of Nations, 1940.

[4] Where most of the people can read and write a census can be fuller and more accurate than among an illiterate people. Also great mobility among a people, as in the United States, makes for less accuracy in the census. No census is quite accurate; but I have no data for a numerical estimate of census errors.

TABLE 1.—*Estimates of the world's population* *

Authority	Date	Population in millions
E. Levasseur	1908	1,626
Sir G. H. Knibbs	1914	1,649
Times' Atlas	1921	1,646
International Institute of Agriculture	1921	1,820
Statistical Yearbook of the League of Nations	1931	2,025
Do	1940	2,145

* Levasseur, La répartition de la race humaine, in the Bulletin de l'Institut International de Statistique, 1909, pp. 48–63; Knibbs, The mathematical theory of population—Appendix A to the First Census of the Commonwealth of Australia, 1917, p. 31; The Times' Atlas, London, 1922, plates 5 and 7; International Yearbook of Agricultural Statistics, 1909–1921, published in 1922 at Rome; Statistical Yearbooks of the League of Nations, 1932–33, and 1939–40. See also A. M. (now Sir Alexander) Carr-Saunders' World Population, Oxford, 1936.

These estimates do not form a concordant series. In Europe and North America the chief areas of doubt were Russia and Mexico respectively. In Asia the whole difference may be explained by various estimates of the population of China; but there is equal uncertainty as to the numbers of the peoples of southwest Asia. There were wide differences in the estimates of the population of Africa, which illustrate the difficulty in respect to the numbers of barbarian peoples. Estimates of the population of the Belgian Congo have ranged from 30 millions down to 8 millions.[5]

The next table (2) states some of the recent estimates of the population of China, to illustrate the differences in regard to the principal area of doubt in estimating the total numbers of mankind.

[5] E. M. East, Mankind at the Crossroads, p. 100, London, 1924; Levasseur, op. cit., gives 20 millions. Philip's Handy Reference Atlas, London, gives 16 millions in 1900 and 20 millions in 1913. Annuaire de la Belgique et de la Congo Belge, 1914, gives 15 millions, and in 1945, 10 millions.

TABLE 2.—*Population of China and its dependencies* *

Authority	Date	Population in millions
Mingchingpeng Census	1910	324
Government Gazette, Pekin	1911	315
China Continuation Committee	1918	441
Chinese Post Office	1920	428
Times' Atlas	1921	321
Chinese Maritime Customs	1922	443
Chinese Post Office	1922	433
Statistical Yearbook of the League of Nations	1931	450?
Ministry of the Interior (Nanking)	1931	475
Statesman's Yearbook	1931	486
Statistical Yearbook of the League of Nations	1940	450?
Statesman's Yearbook	1946	458

* The first and fourth figures are from the China Yearbook, 1922; the second, sixth, seventh, ninth, tenth, and twelfth from the Statesman's Yearbook, 1924, 1932 and 1946; the third is from P. M. Roxby's The distribution of population in China, in the Geographical Review, January 1925; the fifth is from plate 7 of the Atlas.

The census of 1910, which was the basis of the estimate of 1911 and perhaps also for that of the Times' Atlas, was a census of households. The multiplying factor (the assumed average number of persons per household) was not the same in all the provinces, and is open to doubt.

From the figures here given it appears that the population of the world has increased by about 25 percent since 1911, and that of China by nearly 50 percent. But since 1911 China has suffered from revolution, followed by years of internal disorder, from civil war, and from foreign invasion on a very large scale. There have also been floods and famine and pestilence. The extent of these disasters and their persistence over more than 30 years make it unlikely that there has been any considerable increase in the population of China over this period. In India the influenza epidemics of 1918–20 almost canceled

the natural increase of population for the intercensal decade 1911–21, in which the net increase was only 0.9 percent. Europe has undergone two great wars, and the resulting famines and pestilence, since 1914; while Russia has also suffered revolution, civil war, and further famine. These facts taken together make it improbable that there has been any large increase in the total world population since 1914, in spite of the growth in the New World.

In view of these doubts and of the variations in many of the estimates which have been quoted, it is impossible to give an exact figure for the world's population. The total is probably somewhat less than 2,000 millions (2×10^9).

Growth

The experience of the civilized lands during the last two centuries has accustomed us to the conception of a continually increasing population. From 1801 to 1921 the population of England and Wales multiplied more than fourfold[6] in spite of a considerable emigration. Since 1800 the total population of Europe has increased from 175 millions[7] to 500 millions, in spite of the emigration of not less than 40 million[8] people. Under specially favorable conditions some smaller populations have increased even more rapidly. The French Canadians now number about 4 millions. Practically all of them are descended from the 5,800 immigrants who reached Canada before A. D. 1680 when immigration from France ceased.[9] This gives more than six-hundredfold increase in 260 years.

During the first decade of this century the mean rate of increase in the countries which had regular censuses was 1.159 percent per annum.[10] At this rate the numbers would be doubled in a little more than 60 years. If this had been the average rate of increase in the past, the whole of the present population of the world would be descended from one couple living near the end of the first century B. C. (the date of the expulsion from the Garden of Eden?). If it could be maintained in the future, then in another thousand years the earth would have about 25 million millions (25×10^{12}) of human inhabitants, i. e., more than one to every square yard of land. Such calculations make it very obvious that the recent average rates of increase among the civilized peoples are far greater than those which existed in the past; and also that such rates of increase cannot be maintained for any considerable time.

Evidently we have been living in a period of exceptionally rapid increase of population. But it is clear that we are approaching the end of that period; for the birth rates are now falling, more rapidly than the death rates, in a large part of the civilized world. While in the past the direct check to a too rapid increase in numbers was usually the existence of a high death rate, in particular of high rates of infant mortality, it is now attributable chiefly to a fall in the birth rate. Mankind is now able to choose which of these two checks shall be applied; but one of them must be. If the naturally rapid increase in numbers is not controlled by human acts, the appeal will be to the ancient trinity of "war, pestilence, and famine." For the surface of the earth is incapable of expansion; and its resources, though great and capable of much fuller utilization, are limited.

[6] From 9 millions to 38 millions; figures from the Census Reports.

[7] Estimate of Levasseur, op. cit.; and see J. Haliczer's The population of Europe, 1720, 1820, 1930, in Geography, 1934.

[8] To the United States alone more than 33 millions. F. J. Warne in Annals of the American Academy of Political and Social Science, January 1921.

[9] G. E. Marquis on p. 7 of the volume Social and economic conditions in Canada, published by the American Academy of Political and Social Science, May 1923.

[10] Knibbs, op. cit., p. 31. See also article by F. Shirras, in the Economic Journal, March 1933.

Recent Expansion

We may note very briefly the conditions which made possible the great and sudden expansion in the numbers of the European peoples in the nineteenth century. Evidently these conditions affected the English-speaking peoples to a greater extent than any others; for their numbers have increased ninefold since the beginning of last century. They now form more than a fourth of all the peoples of European origin, whereas in 1800 they were less than one-eighth.

It is clear that this particular expansion is chiefly due to the peopling of North America; for that continent now contains two-thirds of the English-speaking peoples, whereas it contained only one-fifth of them in 1800.[11] The growth began with the industrial revolution, when the application of mechanical power increased the production of manufactured goods and so led to an increase in the populations of the industrial areas. The increased demand for food was at first met by a more intense cultivation of the homeland; but the insufficiency of this source of food was shown in the "hungry forties" of last century. The pressure of a hungry people removed fiscal barriers which had hindered the free import of food, while the improvements in transport made the virgin lands west of the Appalachians accessible, and the population of Great Britain multiplied on a food supply obtained from oversea. The demand stimulated the colonization of North America and the even greater increase of its population. But there is little likelihood of the discovery of another New World to allow another such expansion of numbers until man conquers the equatorial jungles.

Distribution

The final limiting factor to the growth of population is that of the food supply; and since man must obtain practically the whole of his food from the land,[12] the next important questions in this study are "What is the extent of the available land?" and "How much of this land is capable of being used for the support of mankind by the production of materials for food, shelter, and tools, with which to satisfy human wants?"

The area of the lands outside the polar regions is known to a fair degree of accuracy. Omitting the permanently icebound lands, the total area of the remainder, the available land, is about 50 million square miles.[13] Thus the average density of population is nearly 40 persons per square mile, a figure which may be of some interest as a basis for comparisons; though in fact the density varies very widely, and the most characteristic feature of the distribution of population is its extreme unevenness.

Of the total of 2,000 million people the greater number live in three comparatively small regions of particularly favorable environment (see fig. 1). In the northwest of the Old World the populous region of Europe is limited on the north by the parallel of 60° N. latitude and the upper valley of the river Volga, on the east by the Ural Mountains and the Caspian and Persian Deserts, and on the south by the

[11] Populations of the English-speaking peoples in millions (Whites only):

1801	British Isles		15. 9
	Canada		0. 1
1800	U. S. A.		4. 3
	Total		20. 3
1931	British Isles	49	
1941	Australia and N.Z.	9	59
	South Africa	1	
	Canada and Newfoundland	8	127
1940	U. S. A.	119	
	Total		186

[12] It is not possible to determine with any precision what amount or proportion of human food is obtained from the sea. This does not affect the value of our estimates of population capacity, since these supplies are included in the resources of the existing populations on which those estimates are based.

[13] C. B. Fawcett, The extent of the cultivable land, in Geographical Journal, December 1930.

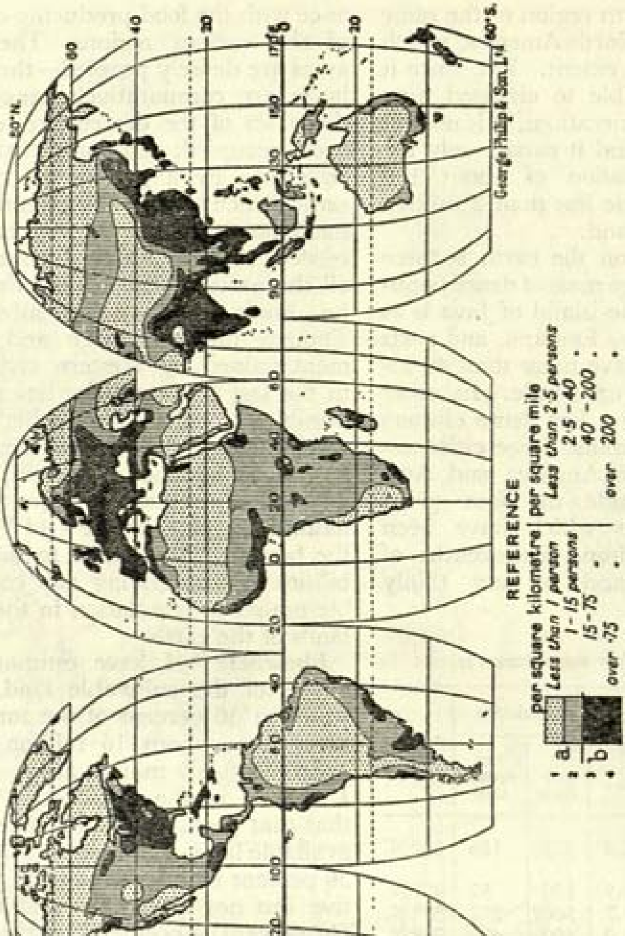


FIGURE 1.—World: density of population.

Note that the mean density for all the land is about 15 persons per km.[3] (40 persons per square mile), so that *a* marks densities below the average, *b* marks densities above the average.

Sahara-Arabian Desert.[14] This region contains more than 500 million inhabitants on less than 3 million square miles of land. In the Far East the similarly populous region which includes most of China and Manchuria, the Japanese Empire south of 40° N. latitude, and Tonkin, is occupied by nearly as many people on an area of barely 1,700,000 square miles. And in India and Ceylon, between the Thar Desert and the eastern edge of Bengal, there are 400 million people on about a million square miles of land. Thus in these three major populous regions of the Old World there are crowded together nearly two-thirds of the world's population on one-eighth of the available land.

[14] See also Sir H. J. Mackinder, Democratic ideals and reality, London, 1919; and C. B. Fawcett, Centers of world power, in the Sociological Review, April 1926, and The changing distribution of population, Scottish Geographical Magazine, November 1937.

There is a fourth region of the same type in eastern North America, which is comparable in extent. But, since it has been accessible to civilized man for only a few generations, it is not yet fully occupied; and it carries only the moderate population of about 130 millions on a little less than 2 million square miles of land.

Nowhere else on the earth is there any similarly large mass of dense population; though the island of Java is as densely peopled as England, and parts of West Africa have more than 40 inhabitants per square mile. In other regions there are a few dense clusters on small areas around large cities, especially in South America and Australia. But outside the four great populous regions which have been noted the remaining six-sevenths of the available land is very thinly peopled.

TABLE 3.—*The four major human regions*

Continuous habitable region	Area in millions of square miles	Population: In millions	Population: Per square mile	Central latitude
Europe	2.8	520	186	50° N.
Eastern North America	1.9	130	52	40° N.
Far East	1.7	500?	292	35° N.
India	1.0	400	400	25° N.

Next we may briefly consider the reasons for this, at first sight peculiar, distribution. Rather more than three-fourths of mankind dwell in the Old World, by which is meant that part of the earth which has been accessible to civilized men during all the historic period, in contrast to the New World which has been similarly accessible only since the Age of Discovery at the end of the fifteenth century. The Old World, as thus defined, includes most of Asia, Europe, and Africa north of the Sahara, and nearly half of the available land.

Over this vast area the population is in fact distributed in general accordance with the food-producing capacity of the various regions. The fertile areas are densely peopled—the barren lands are comparatively empty. All the oases of the deserts are, or have been, occupied; and many of them are crowded. By a process of trial and error, which has already extended over some thousands of years, men have succeeded in establishing themselves in all the parts of these lands which can be made to provide subsistence. Though the knowledge and equipment gained by Western civilization in the last two centuries has made it possible to utilize lands which could not be occupied by civilized man before, as for instance in Siberia, yet the general adjustment of population to natural resources in the Old World is the best available guide to the possibilities of maintaining any comparable masses of population in the newer lands of the earth.

Elsewhere [15] I have estimated the extent of the cultivable land of the world at 30 percent of the total land area, i. e., about 16 million square miles or 10,000 million acres. Hence I assume in the rest of this address that that area, less than a third of the available land, is cultivable. Another 30 percent may be classed as productive but not cultivable; and the rest (40 percent) is occupied by the deserts (cold and dry). (See fig. 2.)

The productive but uncultivable third of the land is mainly divided between areas of forest and poor grazing land, such as the mountain and hill pasture of northwest Europe and the semiarid range or bush of North America and Australia. The wetter areas of this land are often suitable for forest; so are some considerable areas on the margins of the tundra, where the hardier conifers can grow although the lack of sufficient summer heat prohibits agriculture. The semiarid regions, and the summer pastures of the tundra and the high mountains, are likely to remain grazing lands.

[15] Geographical Journal, December 1930.

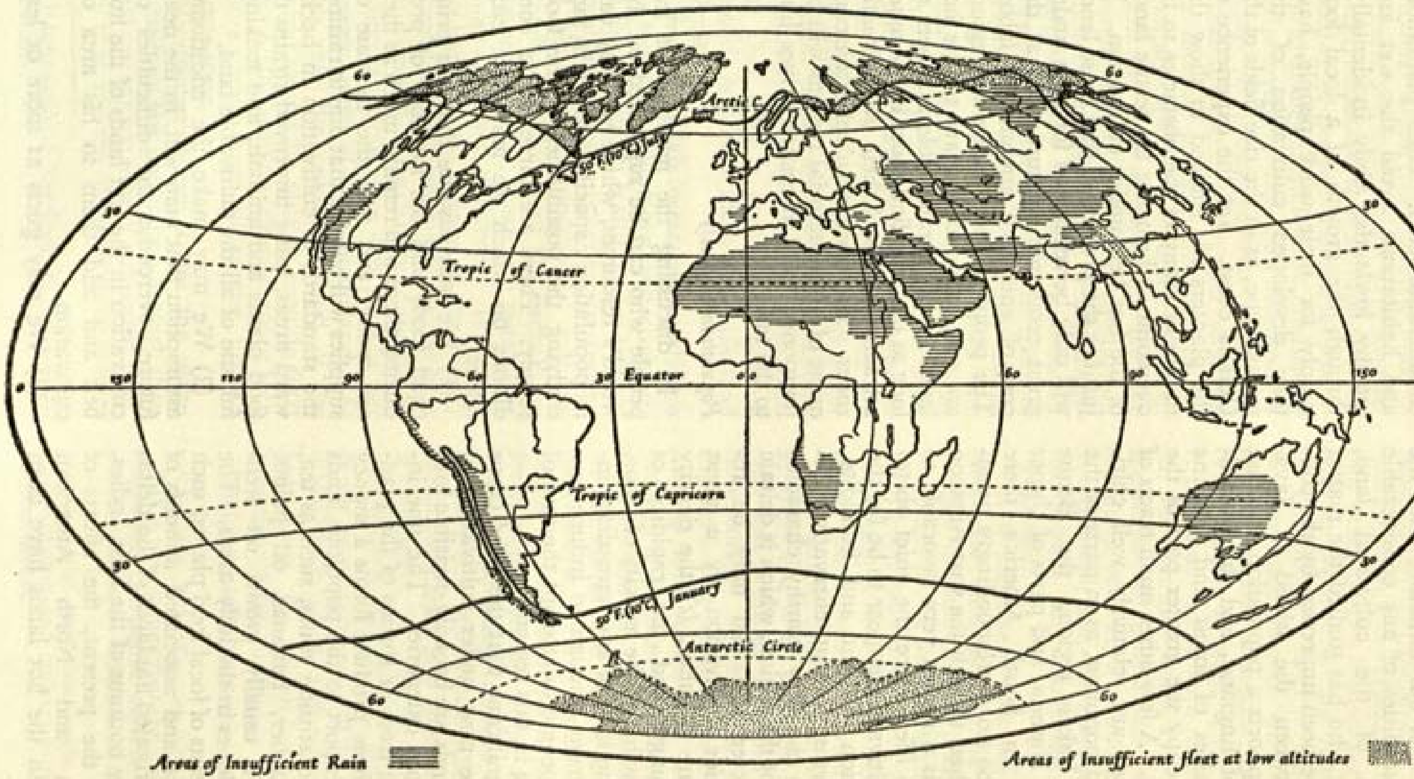


FIGURE 2.—Distribution of cultivable land. The shaded areas are the desert, and so uncultivable regions. The areas left white include the cultivable land, and also areas which are uncultivable because of steep slopes, poor soils, swamps or other local disadvantages, though they may be occupied by forest or poor grazing land.

The wet forested lands of the hot belt, which are included in the cultivable land of our estimate, offer the chief possibilities of any considerable extension of the cultivated land. Everyone who has studied the matter must have been impressed by the contrast between the island of Java, which supports a population as dense as that of England, and the uncultivated wastes of forest and savanna which occupy the greater part of the hot lands. A few other small tracts of these lands are relatively well cultivated and populous, as in parts of the African Lakes region, the Benue Valley of Nigeria, and parts of Upper Guinea. In South America there seem to be no correspondingly populous patches, though the vast Amazon lowland is a region very favorable to vegetable life. Here the chief obstacles to cultivation appear to be (*a*) the combination of heat and humidity, which forms a most enervating climate, (*b*) the very marshy character of much of the region, which is deltaic in character and can only be reclaimed for cultivation by a great expenditure of labor, (*c*) the density of the jungle and the rapidity of plant growth, (*d*) the scarcity of labor, and (*e*) the lack of any immediate incentive strong enough to induce any civilized people to attempt the task of colonizing in this region.

It is significant that the chief crops which are now under cultivation in the hot lands are broadly divisible into two distinct categories. The one includes the trees or shrubs of the plantations whose produce forms a money crop for export to the populous lands of the midlatitude zones, such as tea, coffee, rubber, bananas, oil palms. These are usually grown on well-drained slopes in the hilly areas. The other consists of local food plants, such as the rice and associated annuals of the wet irrigated flat lands of the deltas and valley bottoms of the East Indies.

Up to the present, the efforts of European and North American planters in the hot lands have been directed mainly to the first group of products, and therefore to areas of considerable relief. Their plantations and habitations avoid the wet and marshy lowlands. Only incidentally, through the growth of a local food supply for their work people, have they developed cultivation of the second type, as in the rice fields of the Guiana coast. Yet the experience of the planters has sufficed to show the nature of many of the obstacles to be overcome in bringing the fertile lands of the hot belt under cultivation. It justifies the prediction that these lands will only be reclaimed for man under great economic pressure, and at the cost of enormous amounts of labor. The peoples of the temperate regions are not likely to migrate to the hot lands in any considerable numbers so long as they can find room in the more attractive lands of their own climatic zones. Therefore, man's effective conquest of the equatorial regions will be postponed until necessity drives him to the task.

Population Capacity

In discussing the numbers of the people who can be supported on the world's resources, which we may call its population capacity, we are in fact studying the possibilities of the food supply. There are three sets of conditions on which we may base estimates:

(1) We may assume that the principal foods and the methods of producing them will remain much as they are today, and that the increase of supplies will only be that due to raising the standards of cultivation in backward areas, using improved strains of food plants and animals, and making full use of all the cultivable land.

(2) We may make the additional assumption that man will, in the near future, overcome the difficulties of cultivation in the wet lands of the hot belt and add them to his area of cultivation.

(3) We may guess at more or less

speculative advances in the developments of science applied to food production, which may enable man to increase the food supply very largely.

Also we should bear in mind that the number of people who can be maintained at any given level of production varies inversely with their standards of living. It seems probable that the civilized peoples will prefer to check the increase in their numbers rather than accept a lower standard of living.

On the first assumption, that the present methods of food production will be extended but not greatly modified, we may calculate the world's population capacity on the basis of France and the area formerly known as British India. These lands are chosen because (*a*) both of them ordinarily produce sufficient of their staple foods for their own needs, on their present standards, (*b*) both are old lands, and are fully peopled under present conditions, (*c*) fairly reliable statistics are available for both, and (*d*) they offer a contrast in type of climate and have different staple food plants.

France is a fair instance of conditions in one of the long-civilized countries of Europe which is still, under normal conditions, self-supporting in respect of her necessary foodstuffs; and the standards of living of the French are probably a little above the average of those of the rest of Europe. In France no less than 90 percent of the land is classed as productive and half of it as cultivated.[16] The density of the population is a little over 400 persons per square mile of cultivated land. At this rate the cultivable land of the world would be able to provide food for 6,500 million people (65×10^8), more than three times the present population.

In former British India the mean density of the population is more than 600 per square mile of cultivated land, so that on the present standards of India the world might maintain nearly 10,000 million (10^{10}) inhabitants, five times the present population.

But it should be remembered that in bad years neither France nor India is able to produce all the food needed by her people. After a bad harvest France must import wheat; and a failure of the monsoon rains may bring famine to large areas of India. If the whole world were peopled up to its full normal capacity on these standards of production and consumption of food, it would in fact be overpeopled, and the surplus population would be periodically removed by famine.

On the estimate that 2½ acres of cultivable land is, on the average, needed to support one person at the standards of the advanced countries,[17] the 10,000 million acres of such land could support only 4,000 million people at this standard of living.

Our second assumption is that the pressure due to an increasing population and a falling standard of living may compel mankind to utilize all the cultivable lands of the hot belt at least as fully as those of some small areas in it are now used. At this rate that portion of the cultivable land which lies in the hot belt, nearly a quarter of it, or 4 million square miles, might be capable of producing food[18] for a population as dense as that of Java. That island contains 42 million people on 50,000 square miles of land, of which a little less than 60 percent is cultivable, so that the density per cultivable square mile is about 1,200. If we take France as our basis for the midlatitude lands and Java for the hot lands the possible population becomes 9,600 millions (96×10^8), which is nearly the same total as our

[16] International Yearbook of Agricultural Statistics.

[17] See, e. g., E. M. East, op. cit., and others.

[18] It is well to note that the possibilities of transporting perishable foods are likely to improve still more. Hence such an increased amount of food might be used to feed the people of the temperate lands as long as their economic and military power enabled them to take it.

817369—49——30

second figure based on Indian standards.

In relation to the third assumption we should note the existence of such views as those put forward by the late Prince P. Kropotkin,[19] who could see no limits to the productivity of the land and claimed that the food production of England, and other countries, could be easily doubled by the application of intensive methods of cultivation. Such an increase would, however, more than double the labor cost of the products and so tend to lower the standards of living. It is true that agricultural productivity can be increased by such expenditure of labor and capital, and still more by the application of the results of scientific investigation into its problems. Many optimistic forecasts have been made; but I know of no data sufficient to justify even an intelligent guess at the limits of such productivity.

It is clear from the estimates here given that the world, as a whole, is capable of supporting a population much more numerous than that which it carries today. The immediate problems of overpopulation are limited to some few areas; and the present-day pressure of population [20] is not against the limited resources of the earth but against the various barriers, natural and artificial, which hinder access to those resources. Yet the fact that the size and natural resources of the earth are fixed and limited ensures that its human population cannot increase indefinitely. With our present powers of production the world may be able to support three times its present population in reasonable comfort. But if the present rates of increase are maintained that number will be reached in less than a century from now.

[19] P. Kropotkin, Fields, factories and workshops, London, 1898, and several later editions.

[20] C. B. Fawcett, Pressure of population, in the New Commonwealth Quarterly, London, January 1943.

Mexican Calendars and the Solar Year [1]

By HERBERT J. SPINDEN, *The Brooklyn Museum*

[With 7 Plates]

Then the face of the sun was eaten; then the face of the sun was darkened; then its face was extinguished. They were terrified when it burned on high, at the word of their priest to them, when the word of our ruler was fulfilled at the word of their priest to them.

Book of Chilam Balam of Chumayel.

The calendar and the dictionary are always with us, for bad counting of days and bad spelling of words are besetting vices—expensive ones, too! Yet what we need most in the way of a business timetable was invented in Central America 26 centuries ago: a year cut up into 13 months of 28 days, or exactly 4 weeks each, and at the end, where it would do most good, an extra day or two of festival.

Quite different, however, from our likely uses of such a formal calendar were the original ones of the Maya. For them this was a standard calculator to use with a 13-part zodiac in measuring movements of the moon and planets from star to star. Its natural period, then, was the sidereal year and the recession of its short scale was checked by reference to the eternal chronometer of distant stars.

Long before it became smart to name the moons of a luni-solar calendar, primitive man clocked the changing appearances of nature against rising and setting constellations. He thought the sidereal year was one with the tropical year. But really it is the swinging points of sunrise and sunset which correlate vitally with those changes in solar light and heat necessary to life. These regulate our earthly calendar of life and death. Yet the stars and planets which attest the glory of the Lord embody ultimate natural law. The difference between the sidereal and tropical year amounts to only 1 day in a long lifetime. On the other hand, attempts to use the obvious moon leads to headaches.

A Fateful Eclipse

Safely settled as farmers in lowland Central America, the people we call Maya thought their medicine men or shamans should find a way to regulate the weather. It seems those shamans accepted the suggestion. Ultimately they learned to prophesy celestial events and assumed the status of theocrats. It seems a crisis had come on November 10, 752 B. C., when a terrifying solar eclipse crossed northern Central America, to be followed 177 days later by a second solar obscuration just as portentious.

That first fateful eclipse is now recognized as the ceiling date of Maya science and the first credible time point in New World history. For then and there the Maya shamans began to keep a careful count of suns and moons to learn the why and wherefore of eclipses.

Much water passed under bridges before that date could be written in

[1] Fifteenth Arthur lecture, given under the auspices of the Smithsonian Institution March 3, 1948.

Maya numerals and hieroglyphs. It seems that notations of numbers did not yet exist, nor names and symbols applying to such a chronological problem. Ultimately they wrote with bar-and-dot numerals in place values the date which we transcribe as 6–12–19–4–8 and reduce to 957328 in Arabic figures. It was completed by the day name and month place which we write 12 Lamat 1 Muan. My Correlation A converts this Maya Day 957328 by the addition of 489384 into Julian Day 1446712.

The crucial eclipse was a starting point or zero and out of that count came a simple numerical relationship which conceals a thoughtful reduction out of a hurly burly of events. It did not lead the Maya to our materialistic concept of the universe. Perhaps our celestial bodies were celestial souls to the Maya, spiritual powers not given to capricious acts. Perhaps to them natural law was supreme intelligence to which gods most of all were bound. The Maya deified the sun, moon, and planets, it may be the stars as well. Also they deified their priests and rulers, if not during life, then after death.

That first ephemeris was probably made of strung beads. If the shamans added a bead a day, using colored ones when occasion warranted, and if they kept the record open with continuity unimpaired, then order would be discernible. We have the Dresden Codex to help us with its full calendar of eclipses while the numbers of its preamble can be used to reach precisely that first eclipse. 12 Lamat is one of many eligible days for eclipses which cluster about three foci. A single pattern of intervals in the table I now give may be applied to any eligible date with expectations of eclipse recurrence. Adding 7280 days to a solar eclipse probably gets a lunar one, then 4680 days more carries forward to a second solar phenomenon. This is 11960 days after the first, completing the ancient eclipse cycle of the Maya.

TABLE 1.—*Derivation of tzolkin, tun, and zodiacal year by eclipse correlation*

O=MD 957328=JD 1446712, the solar eclipse on 12 Lamat 1 Muan. Starred items were visible to the Maya. Rule applies to many series.

Solar eclipse +*7280 days*	*Lunar eclipse* +*4680 day*
* 0	* 7280
11960	* 19240
* 23920	31200
35880	43160
47840	* 55120
* 59800	* 67080
* 71760	* 79040
4680= 9 x 520=13 x 360	(18 tzolkin=13 tun)
7280=14 x 520=20 x 364	(28 tzolkin=20 zodiacal years)
11960=23 x 520= 5 x 2392	(46 tzolkin=1 eclipse cycle)

The point I emphasize is that these intervals touch the very heart of Maya mathematics. The tzolkin, peculiar cycle of 260 day names; the tun of 18×20=360 days, incongruous place value in a system otherwise purely vigesimal; even the 364-day timetable which I have recommended to the modern businessman, appear as factors. Of these, the tzolkin is most important. It is half of 520 days, which in turn equals three eclipse seasons with a minute error. Now the eclipse season, or draconic half year, concerns placing of lunar nodes indispensable to eclipse calculations, and its discovery required a touch of genius.

Invention of the Maya Time Machine

In 1930 Ludendorff, writing in Germany but using my Correlation A, explained the tzolkin as an eclipse derivation with 1 Imix as a focus of eclipses before the establishment of

the Maya day count on August 6, 613 B. C. This basic date was part of my original explanation in the reduction of Maya chronology in 1924. Ludendorff's results coincide with those of the table given above, although his method of derivation might seem too sophisticated for use by the early Maya.

The invention of the tzolkin and the decision to use the tun as third place value in numerical notation was made before the establishment of Baktun 7. The word baktun itself means 400 tun. The chronological establishment allowed 7×400 tun for the unknown past and gave a formal starting point for historical reckoning. Actually Baktun 7 was not the first authentic Maya date, for a tenuous counting system extended back to the first eclipse of the Maya ephemeris already discussed. I write these eras:

Era of the World: 13-0-0-0-0, 4 Ahau 8 Cumhu, October 15, 3373 B. C.
Era of History: 7-0-0-0-0, 10 Ahau 18 Zac, August 6, 613 B. C.

Contemporary documentation is lacking. Nevertheless, I located in 1930 two considerable sequences of eclipses on 12 Lamat. These were alternately solar and lunar, the first series containing the data in the break-down of the 11,960-day cycle shown above. The first series ran from November 10, 752 B. C., to May 2, 555 B. C., as regards eclipses of the sun. The second series began after a lapse of 1,508 calendar years, as the equivalent of 1,507 tropical years, on May 2, A. D. 952. A grand round of the Maya civil calendar served here as an eclipse interval! This second series of 12 Lamat eclipses ran to January 15, A. D. 1247, embracing the time when the Dresden Codex most probably was compiled. The explanation of these two widely separated historical places for eclipses on the same tzolkin days is seen in the recession of lunar nodes in respect to the double tzolkin. When this recession plus an eclipse half year amounted to 260 days, eclipses were reestablished on their old day names. This is why term 10 of the Lunar table, 31×11960+260, makes it possible to handle eclipse matter across so many centuries. It was Dittrich who showed how the Maya themselves could reach the 12 Lamat 1 Muan eclipse from Maya zero.

Most probably counting days at the establishment of Baktun 7 merely combined tun numbering with tzolkin designation. The days of these eras are 4 Ahau and 10 Ahau, respectively. These days fall 140 and 160 positions after 1 Imix. When the tzolkin was established is uncertain. There were several eclipses on 1 Imix and others on 13 Ahau, one day earlier.

But almost certainly month positions were not assigned to 4 Ahau and 10 Ahau until after 580 B. C. When the Maya organized their civil calendar of 365 days, this was arranged to depart from the winter solstice, as O Pop.

I return to the construction of 13 and 7 seen in the names of the eras. Seven and thirteen are prime numbers which added together make 20, second place value in Maya notation of numbers. This combination had a mystical connotation for the Maya. The word for the 20-day period is *uinal*, derived from *uo* meaning moon. Simple pictures of the moon have the value 20 or zero. Undoubtedly the moon or month gave rise to the second place value in some standardization of counting the bead-a-day record. It seems likely that the days of the sun were registered in shell beads of golden color and that white beads applied to the moon. Jade beads probably were used to mark the year.

In the Song of the Uinal preserved in the Book of Chilam Balam of Chumayel, the uinal is given preference in the creation of time and matter.

> The uinal was created, the day, as it was called, was created, the heaven and earth were created, the stairway of water, the earth, rocks, and trees; the things of the sea and the things of the land were created.

Thirteen entities, seven entities, one. So it spake when the word came forth at the time there was no word.

The uinal was created, the earth was created; sky, earth, trees, and rocks were set in order; all things were created by our Lord God the Father. Thus he was there in his divinity, in the clouds alone and by his own effort, when he created the entire world, when he moved in the heavens in his divinity. Thus he ruled in his great power. Every day was set in order according to the count, beginning in the east as it is arranged.

Semantics of the Maya uinal follow in part from the circumstance that Imix is beginning and Ahau is end in numerous implications. The Maya combination Ahau Imix was old ending and new beginning. What is true of the uinal in this regard is true also of the tun, katun, baktun, pictun—always they begin with Imix and end with Ahau. But the 20 names which compose the uinal have a continuous association with 13 numerical coefficients, all combinations running out in $13 \times 20 = 260$ days. This is the familiar Maya tzolkin. The cycle of 13 uinal finds its counterpart in cycles of 13 tun, 13 katun, etc. Always there is a basic construction of $13+7=20$, in the days of the uinal, the uinal of the tun, the tun of the katun, etc. The 20 names and 13 numbers combine in the invariable table of the tzolkin which enters into and classifies all measures of time.

Baktun 13, Era of the World, is construed as the end of one baktun numbering cycle and the beginning of a fresh one. But the seven periods of 144,000 days each which carry on to Baktun 7 really established the end of a pictun.

What One Ancient Date Reveals

Even though no inscriptions actually survive from early centuries when the Maya were laying the foundations of their science of astronomy, we do have one date which I venture to call an astronomical bench mark. It is recorded with other much later dates and connected with one of these by a distance number which amounts to more than a thousand years.

Morley was first to decipher the inscription on Altars H′ and I′ at Copan in abstract terms of Maya chronology. Later, Teeple examined the intervals just as abstractedly, concluding properly enough, that they dealt with the Copan formula, 149 lunations=4,400 days. On Moon day 22 it could be carried back to Maya zero. But Teeple might have gone farther. The long interval of the inscription amounts to 365,820 days which is 1,407 times the tzolkin as well as 1,005 zodiacal years and therefore 201 times 1,820, their common multiple. The pictured zodiac of 13 constellations each trimmed to 28-day sections is found in the Peresianus Codex. Below the pictures the 1,820-day round displays day names across 5 years of 364 days each.

The Maya, lacking angle-measuring instruments, fell back on the 360-day tun, the 364-day zodiacal year and the 365-day civil year to effect better divisions of the uneven tropical and sidereal years of nature. With their pictured zodiac they could define stars along the ecliptic. Compare 365820 with departure of three planets from three positions:

Star A to Star A.....34 sidereal revolutions of Saturn 365812.18 days.
Star B to Star B.....1628 sidereal revolutions of Venus 365812.76 days.
Star C to opposite... 538½ sidereal revolutions of Mars 365816.85 days.

Could this be accidental? And what about the distance from Maya zero leading to the ancient date?

$$1020180\begin{cases}11597 \text{ Mercury sidereal } +0.0279\\ 8796 \text{ Mercury synodical } -4.6296\end{cases}$$

This looks as though some Maya calculator thought he could use 100 times the sidereal period of Mercury multiplied by the synodical period, as a preface. The hundredth multiple smoothed out the difficult decimals. An error remained, since the periods of Mercury were about 87.9693 days and 115.8779 days.

But why grope in the dark? The bench-mark date on Altars H′I′

becomes December 11, 580 B. C., in our Gregorian calendar and its 365820-day addition leads to July 11, A. D. 422, which is just 3850 tun after Maya zero. At the outset all five planets known to the Maya were standing within 63° in the morning sky. Mercury and Venus were in close conjunction, and Mars nearby; all three at heliacal rising, or first appearance before the sun. Jupiter and Saturn were higher in the sky: but what a send-off! It justifies the sidereal measurements deduced abstractly for Saturn, Venus, and Mars. I append Muses' calculation:

TABLE 2.—*Planetary positions for JD 1504564, GMT noon ±0.5*

Longitudes

Sun	260.3°
Moon	11.0°
Mercury	242.0°
Venus	240.7°
Mars	250.8°
Jupiter	212.4°
Saturn	187.5°

Configurations

1. Venus, Mercury, and Mars (the first two exact within 2°) in conjunction at heliacal rising.
2. Jupiter in conjunction with North Scale (B. Librae) within 1°.
3. Moon in opposition to Saturn within 1° at Yucatan noon.

NOTE: At Yucatan noon, the moon changes longitude approximately to 8.5° instead of 11° as given.

We must pass on, although many corridors lead out from that planetary rendezvous. One concerns the Supplementary Series, old enigma now solved down to the last legible example. Suffice to say that the Copan formula is concerned but not as Teeple thought. Its 18th multiple amounts to 11 katun which produces a good eclipse interval when 1 day is added. Priestcraft intentionally retained the error in counting forward from ancient eclipses of the moon presumably to get a thaumaturgic anticipation of contemporary ones. The warped lunar days vary in relation to the number of times 11 katun is employed.

The first Supplementary Series occurs on April 5, A. D. 97 recorded on Stela 18 at Uaxactun. A visible solar eclipse preceded this Katun 16 of Baktun 8 by 7 days and a visible lunar eclipse followed it in 8 days.

A New Date at Dzibilnocac

The bench-mark date plus 11 days puts O Pop, Maya New Year, close to the winter solstice. The assemblage of planets had its bearing on the establishment of the Maya calendar equipped with month positions. The meanings of month names and the symbolism of month signs at this time make the calendar conform with the seasons. At this time, also, a Venus calendar was being organized.

The grand round of the Maya calendar returning months to their original places in the tropical year requires 29 calendar rounds of 52 years each, or 1,508 calendar years as the equivalent of 1,507 tropical years. Now Venus repeats her phases in 251 tropical years; six of these cycles are 1,506 tropical years or 1 year less than the grand round mentioned above.

The only reasonably certain date on a Maya building of the Intermediate Period is the abbreviated one on a capstone of the fine Two-towered Temple at Dzibilnocac. The painting shows a Venus god emptying a bag of maize. I read this date as Year-bearer 3 Kan in Tun 9. A reference to the opening date of Venus Calendar A is assumed.

10–18–8–16–4	3 Kan	2 Pop	Dec. 23, A. D. 933.
1–16			
10–18–9–0–0	13 Ahau	18 Uo	Jan. 26, A. D. 934.
16–0			
10–18–9–16–0	1 Ahau	18 Kayab	Nov. 24, A. D. 934.

The splendid structure at Dzibilnocac was built, I think, to celebrate this concordance and the opening of Venus Calendar A featured in the Dresden Codex. Carried back to its beginning, the year is O Pop at sunset December 21, 574 B. C. The Venus dates also repeat at $6 \times 251 = 1{,}506$ tropical years.

The Tropical Year

We think of the tropical year as something in nature which compels us to correct our calendar by inserting extra days. For the Maya, the tropical year was one of several natural cycles equally deserving of attention. To measure all these without fear or favor, days were numbered, named, and given places in the 365-day calendar which in itself could not be amended. In this way the Maya, long before the time of Christ, obtained the same kind of control over diverse phenomena that Scaliger gave to European historians and astronomers in his Julian Period and Julian Day.

The Maya calculated rather closely the recession of 365 days from a tropical year of approximately 365.2423 days, corresponding to about A. D. 200. Mostly they did this by restating for any current year the anniversary of Maya zero, October 15, 3373 B. C. Obviously they could not do this without previously acquired knowledge accruing after Baktun 7, August 6, 613 B. C.

Instead of trying our method of intercalations, they preferred year dials. These give better adjustments, everything considered, than are possible with any leap-year system. We glance at evidence of their skill in using the tropical year, for this had an important reaction on the year dial itself. At Palenque in the Temple of the Cross, a series of dates indicate betterment as time goes on in reaching the anniversary of Maya zero. As an earnest of their ability in astronomical matters, the earliest date, placed 20 days before the initial series, strikes a lunar eclipse. The initial series, also placed before Maya zero, strikes a close conjunction of Venus and Mars. After this, zero is itself declared. Among some 30 dates, 7 deal with Maya zero and the tropical year measured from it. I think the one recording October 10, A. D. 162, especially interesting for on this day took place a lunar eclipse visible at Palenque.

TABLE 3.—*Anniversaries of Maya zero, Temple of the Cross, Palenque*

The Tropical Year is 365.2423 days for all parts of this table.

Date	*Maya day number*	*Maya calendar*		*Gregorian calendar*		*Error*
A...............	0	4 Ahau	8 Cumhu	Oct. 15, 3373 B. C.		0.00
B...............	295482	9 Ik	0 Yax	Oct. 15, 2564		+0.98
C...............	1291128	11 Lamat	6 Xul	Oct. 10, A. D. 162		−3.53
D...............	1295878	2 Caban	10 Xul	Oct. 11,	175	−1.68
E...............	1295879	3 Eznab	11 Xul	Oct. 12,	175	−0.68
F...............	1366007	7 Kan	17 Mol	Oct. 12,	367	+0.80
G...............	1385365	11 Chicchan	13 Chen	Oct. 14,	420	+0.96

References to the place of Maya zero are concentrated at Palenque on the tablet of the Temple of the Cross. I will not comment on three other possible ones. This tablet like those of the Foliated Cross and of the Sun probably were carved about A. D. 430 although mounted in buildings of the seventh century.

Other statements which give approximately the place of Maya zero in historic times occur at most of the important cities on monuments of the first order. At Naranjo, Stela 32 has such a date which combines with others in the year-dial complex yet to be explained. On this monument a theocrat is seated above several tiers of stars and planets.

The most accurate measurement of

the tropical year on the basis of 365.2423 days occurs on Stela 12 at Piedras Negras. This is perhaps the most magnificent piece of Maya sculpture. It pictures a theocrat seated high above bound captives and protected by his own warriors. He wears as headdress the Moan bird or Owl patron of Baktun 13 and operates under other mandates as well. The important part of the inscription is:

9–18–5–0–0,	4 Ahau	13 Ceh	Nov. 16, A. D. 535
1–13,			
9–18–4–16–7,	10 Manik	0 Zac	Oct. 14, A. D. 535.

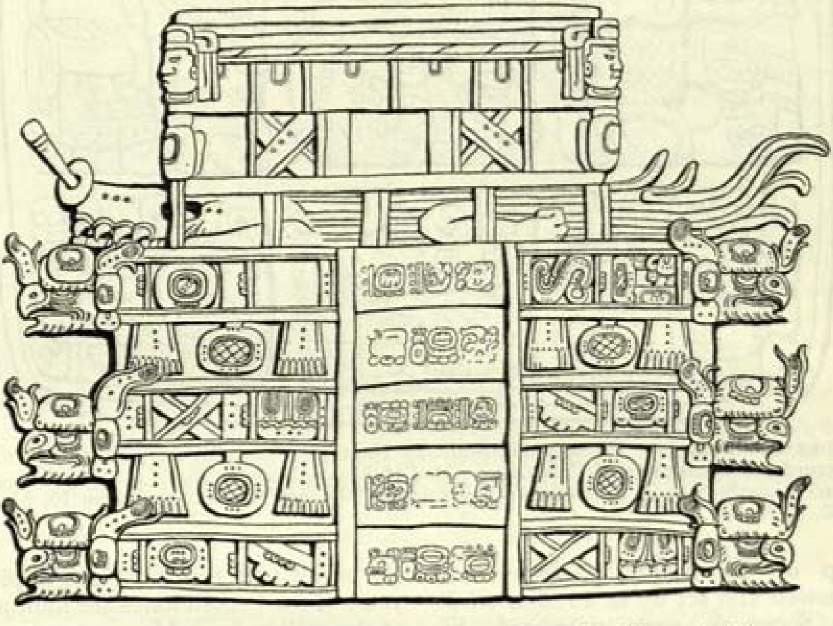


FIGURE 1.—Celestial throne of a Theocrat on Stela 32, Naranjo. The calculation concerns October 15, A. D. 553, also August 28 and 29, 554, with New Year on the Winter Solstice. The Theocrat was responsible, then, for a Year Dial Adjustment. The Owl Patron of Maya Zero terminates the three Celestial Bands.

Here 4 Ahau is the day of Maya zero, 13 Ceh is the month position of Baktun 9, associated with the New Fire Ceremony, and November 16 finds significance as a Venus position. The error on 3,908 tropical years is reduced to .09 of a day—close enough! The superb theocrat is now a dictator using military power to enforce his will. Perhaps a moral could be drawn that when society raises a human being to the skies it runs the risk that egoism will ruin ethics. At any rate, during the sixth century Maya rulers became a warring lot. Head hunting is seen as a new cult.

Rules for the Tropical Year

Temple 44 at Yaxchilan has 15 dates on inscribed steps and lintels. Here was a structure which the Maya thought worthy of signal honors. The original temple had light rubble-and-mortar walls, a thatched roof, and three doorways provided with inscribed steps. Later, stone lintels, carved in an advanced style, were put in place; at this time the upper

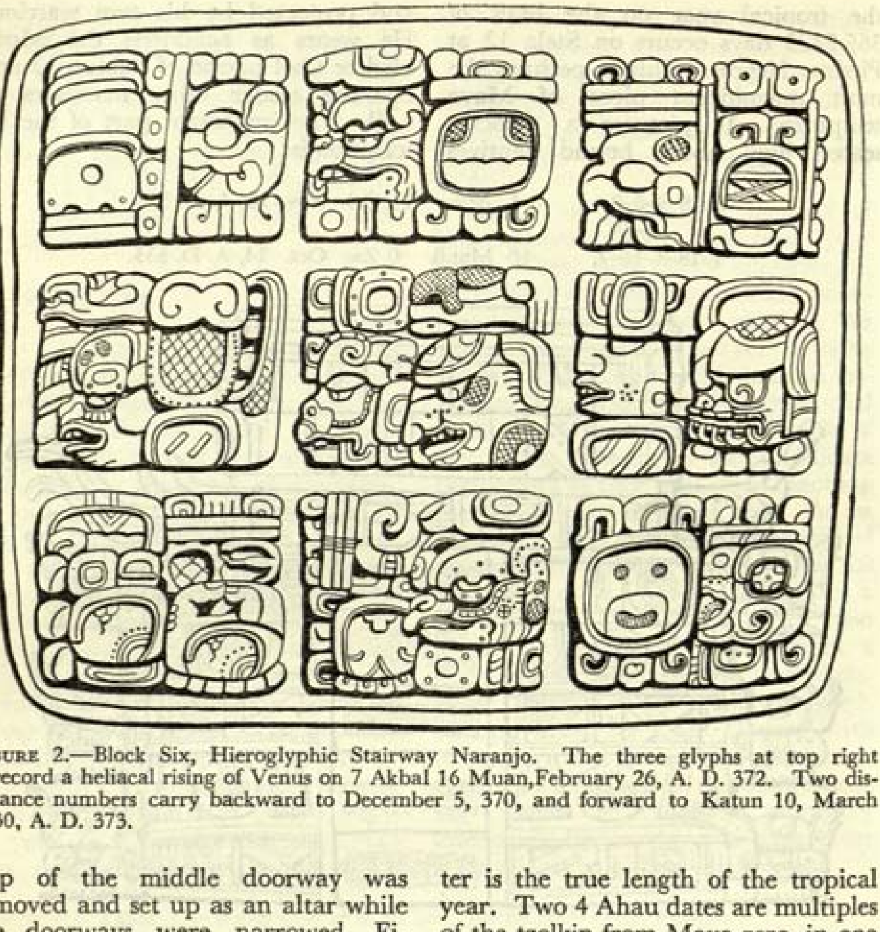


FIGURE 2.—Block Six, Hieroglyphic Stairway Naranjo. The three glyphs at top right record a heliacal rising of Venus on 7 Akbal 16 Muan, February 26, A. D. 372. Two distance numbers carry backward to December 5, 370, and forward to Katun 10, March 30, A. D. 373.

step of the middle doorway was removed and set up as an altar while the doorways were narrowed. Finally, the temple walls were built to support a two-walled roof crest pierced by windows.

Morley deciphered the dates which I have transcribed. The subject matter is the true length of the tropical year. Two 4 Ahau dates are multiples of the tzolkin from Maya zero, in one case at the winter solstice. A 10 Ahau date is similarly a tzolkin multiple from historic Baktun 7, but here it reaches October 16, as the anniversary of Maya zero.

TABLE 4.—*The tropical year on Structure 44, Yaxchilan*

	Day number	Day name	Gregorian date
Era A.........................	0	4 Ahau	Oct. 15, 3373 B. C.
Date 7.........................	1354320	10 Ahau	Oct. 16, A. D. 335
(18×209 tun)=(18×206 tropical years)=365.2427 days			
Era B.........................	1008000	10 Ahau	Aug. 6, A. D. 613
Date 12.........................	1377260	5 Ahau	Aug. 6, A. D. 398
369260 days=1011 tropical years (365.2423 days each)			

The first formula, 209 tun=206 tropical years, is an improvement over the simple approximation, 70 tun=69 tropical years. This taken three times over shows a discrepancy of more than 5 days, which the subtraction of 1 tun from one side and 1 year from the other, balances.

The second formula, 369260 days equal 1011 tropical years, cannot be reduced by common divisors, but the manner in which it was constructed is not far to seek. Formula Two is simply the fifth multiple of Formula One from which is subtracted one Metonic cycle. This celebrated luni-solar period of the Greeks was much used by the Maya, being 1 katun minus 1 tzolkin.

Five times Formula One.............	=376199.5690 days
One Metonic cycle of 19 tropical years..	= 6939.6037 days
Formula Two, 369260 days.............	=369259.9653 days

For comparison Serpent Number G in the Dresden Codex records 12,454,-761 days; this is 34100 tropical years at the value 365.24225833 days, meeting the situation between A. D. 800 and 900 or about the time the Dresden Codex was compiled. All the Serpent numbers run into the future from March 7, A. D. 481. Since Serpent Number G is approximately a common multiple of the synodical revolutions of all five visible planets, it is used here with the tropical or synodical year. Serpent Number E, 12438810 days, is very close on the sidereal year exemplifying, as well, the conformity of sidereal and synodic revolutions of the same five planets with surprisingly minute errors.

Once Again the Year Dial

Old conclusions on Maya chronology eclipsed by the controversy of the '30's over Correlations A and B are rejuvenated in dramatic fashion by the discovery that the axis of the splendid Temple of the Magician at Uxmal recovers the base line at Copan within 3 minutes of arc and with conformity of dates. Places in the tropical year and Venus places as well are recorded in a careful recapitulation of First Empire Maya astronomy in Second Empire times.

The House of the Magician at Uxmal, the eastern facade of the Nunnery and the Snail at Chichen Itza are traditionally linked to Nacxitl Quetzalcoatl, famous Toltec conqueror, reformer, and astronomer, who flourished in the twelfth century. Inscriptions in these cities of northern Yucatan, Mexico, parallel others at Copan, Honduras, and Uaxactun, Guatemala, of a much earlier epoch, in that all belong to the same year-dial complex.

The axis of the Temple of the

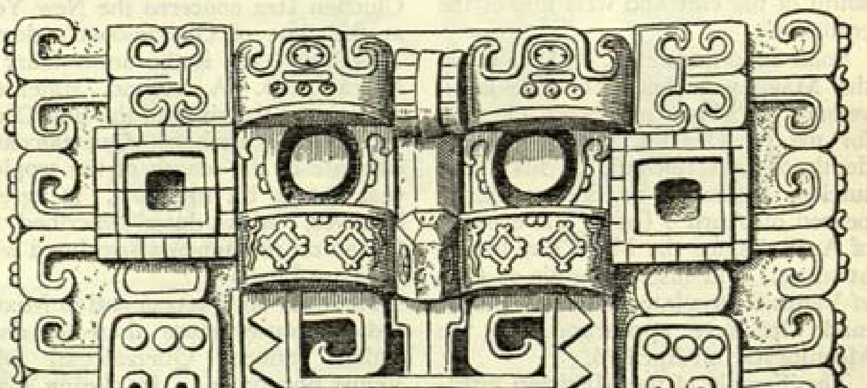


FIGURE 3.—Venus mask on the House of the Magician at Uxmal. Note the sign for 8 days on the upper part of each eye. These are the 8 days between April 4 (evening) and April 13 (morning) when Quetzalcoatl was in the underworld. "For eight days he was bone," says the legend. The underside of the eyes have a design constructed of bones.

Magician is 9°17′ north of west according to readings I made in 1947 with the assistance of Lorenzo Salas Canto and Antonio Canto Lopez, respectively astronomer of the University of the Southeast and director of the Museum of the State of Yucatan. The Astronomical Base Line at Copan was read as 9°14′ by George Byron Gordon on an expedition sent out by Harvard University 50 years ago. That Maya year dial was intended to fix the ceremonial beginning of the Maya agricultural year as the "reciprocal" of Maya zero: that is, the line points to sunset on April 13 and to sunrise on October 15. Two other dates are also reached by the two-way observations, namely, August 30 and February 28, more or less. The August date presumably fixed the planting of a second maize crop.

The year-dial method of the Maya has many advantages over the European method of intercalating extra days in the calendar: it can be applied from any doorstep or fixed place of observation simply by marking the point of sunrise or sunset, as the case may be. With minor adjustments two-way observations give four dates with sunrise or sunset approximately the same angular distance north or south of the east and west line of the equinoxes.

Solar conditions in A. D. 1208 when the Maya year began on the anniversary of Maya zero were checked for me by Charles A. Muses. The death of Quetzalcoatl, or his ritual suicide, occurred as Venus disappeared on April 5 (really the evening of April 4 since the Maya day begins at sunset) and his apotheosis as God of Venus 8 days later when the planet made its first appearance as the Morningstar on April 13.

The Temple of the Magician virtually buries an original temple of the twelfth century under memorial structures. The so-called Annex at the head of a fine stairway has an ornate facade rich with symbolic designs and emphasis on the 8-day visit of the culture hero to the underworld. The apotheosized ruler is supported over two naked figures who have the typical ear ornaments of Quetzalcoatl as identifying adornment. This tableau is in the center of a Venus mask.

At Chichen Itza the eastern facade of the Nunnery again pictures this ruler raised to the skies. A band of zodiacal symbols shows Venus in conjunction with star groups.

The Snail at Chichen Itza is an architectual conventionalization of a sea snail shell. One deciphered date on this facade is April 4, 1280, the seventy-second anniversary of Quetzalcoatl's death. An inscribed stela in the stairway has Venus calculations which reach back to the First Empire. Baktun 10 is recorded when Venus and the Sun were in conjunction, and other dates which Morley has deciphered and I have transcribed.

Quetzalcoatl established the Toltec era on August 6, 1168, exact restatement of Baktun 7, the Maya Era of History. It seems he reconstructed the Maya plan for the duration of the universe, reducing baktun to 52-year calendar rounds. An inscribed tablet found by Edward H. Thompson at Chichen Itza concerns the New Year at the time of Quetzalcoatl's death. This New Year is the anniversary of Maya zero. A second statement appears on the rings of the Ball Court at Uxmal. Perhaps Quetzalcoatl's estimate of the length of the tropical year was a bit too long. It agrees, however, with dates inscribed at Copan on monuments associated with the Base Line.

The data on Quetzalcoatl in Mixtec codices covers more than 90 dates which connect Quetzalcoatl with Venus phenomena. In closing I append a statement of important dates in the life of this great American astronomer who brought to life the art and science of the early Maya.

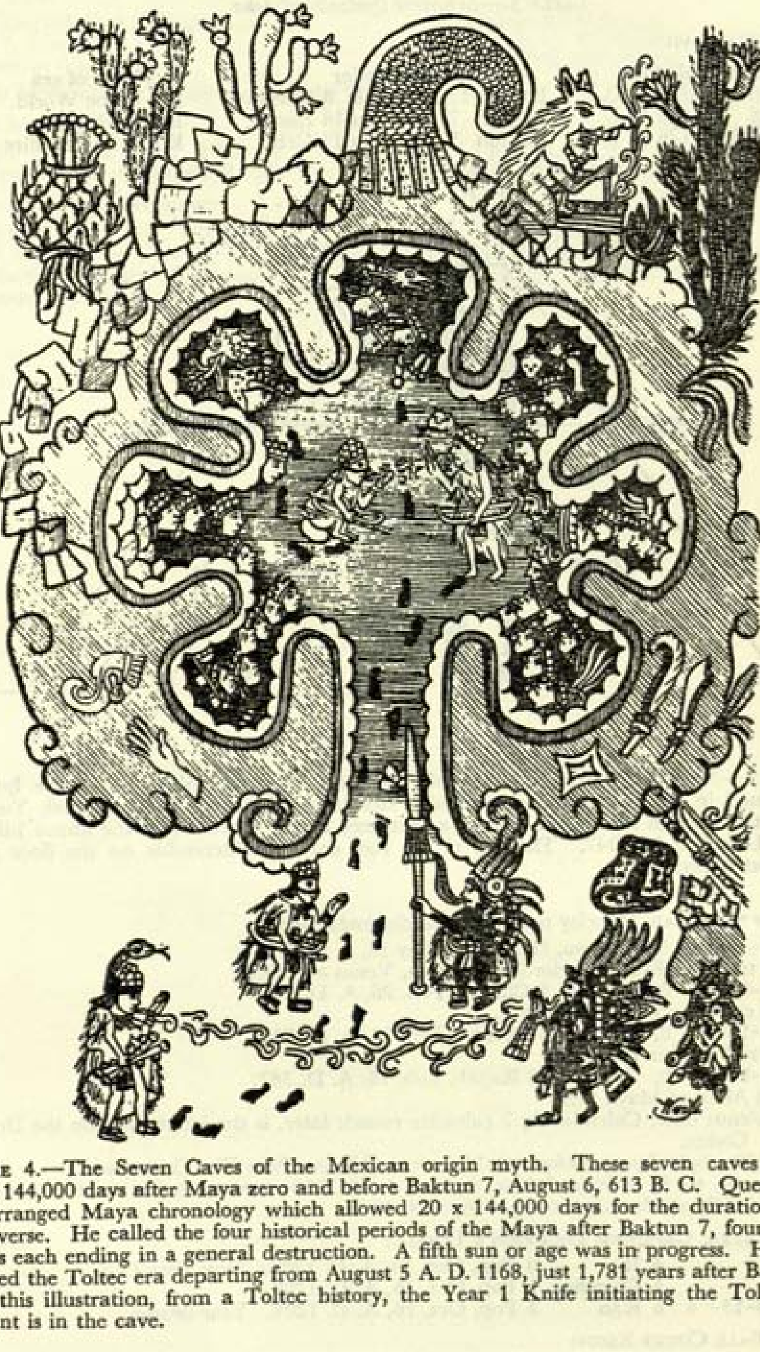


FIGURE 4.—The Seven Caves of the Mexican origin myth. These seven caves are the 7 x 144,000 days after Maya zero and before Baktun 7, August 6, 613 B. C. Quetzalcoatl rearranged Maya chronology which allowed 20 x 144,000 days for the duration of the universe. He called the four historical periods of the Maya after Baktun 7, four suns or ages each ending in a general destruction. A fifth sun or age was in progress. He established the Toltec era departing from August 5 A. D. 1168, just 1,781 years after Baktun 7. In this illustration, from a Toltec history, the Year 1 Knife initiating the Toltec year count is in the cave.

TABLE 5.—*Important Quetzalcoatl dates*

THE MAYA ERAS:

	Gregorian calendar	Maya calendar	Name of era
1	Oct. 15, 3373 B. C.	Baktun 13, 4 Ahau 8 Cumhu	Era of the World
11	Aug. 6, 613 B. C.	Baktun 7, 10 Ahau 18 Zac	Era of History
111	Feb. 11, 176 A. D.	Baktun 9, 8 Ahau 13 Ceh	Era of Sacred Fire

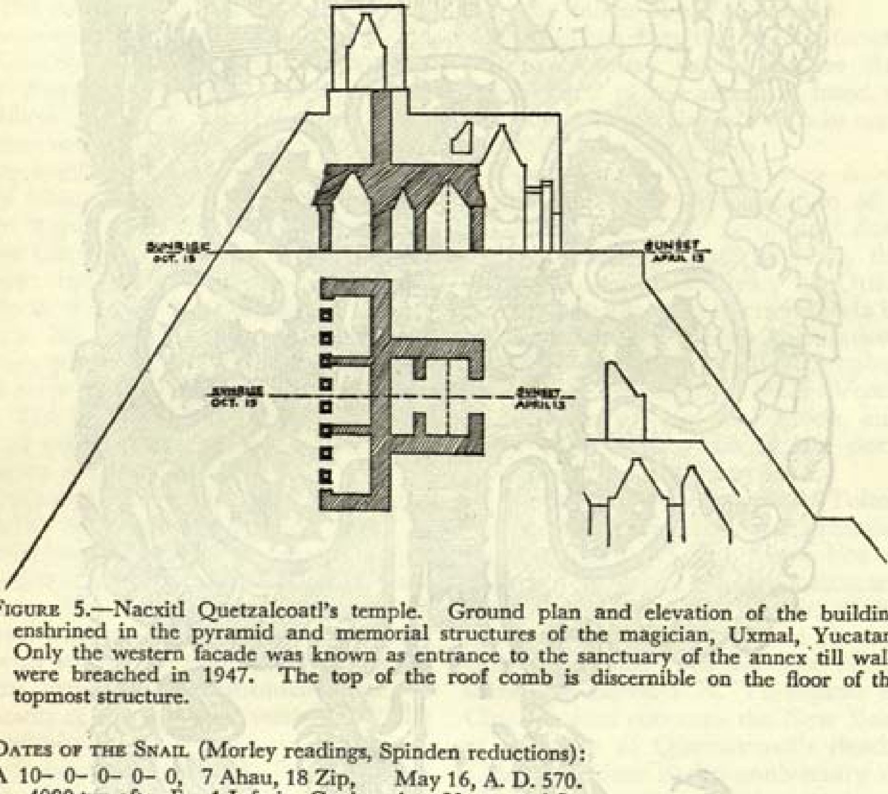


FIGURE 5.—Nacxitl Quetzalcoatl's temple. Ground plan and elevation of the building enshrined in the pyramid and memorial structures of the magician, Uxmal, Yucatan. Only the western facade was known as entrance to the sanctuary of the annex till walls were breached in 1947. The top of the roof comb is discernible on the floor of the topmost structure.

DATES OF THE SNAIL (Morley readings, Spinden reductions):

A 10- 0- 0- 0- 0, 7 Ahau, 18 Zip, May 16, A. D. 570.
4000 tun after Era 1 Inferior Conjunction, Venus and Sun.

B 10- 0-15- 0- 0, 12 Ahau, 8 Cumhu, Feb. 26, A. D. 585.
3960 calendar years after Era 1.

C 10- 0-16- 0- 0, 8 Ahau, 3 Cumhu, Feb. 21, A. D. 586.
586 tzolkin after Era 111.

D 10- 0-17- 0- 0, 4 Ahau, 18 Kayab, Feb. 16, A. D. 587.
(a) 4 Ahau of Maya zero.
(b) Venus date, Calendar A, 7 calendar rounds later, is the latest date on the Dresden Codex.
(c) 609 tropical years before establishment of Toltec New Fire Ceremony.

E 11-16- 0- 4- 1, 3 Imix, 9 Yax, April 4, A. D. 1280: seventy-second anniversary of the death of Quetzalcoatl, evening of April 4, 1208.

CHICHEN ITZA, CAPSTONE THOMPSON'S TEMPLE:

	4 Ik	0 Pop, Oct. 14, A. D. 1209.	New Year Day.
	5 Chicchan	1 Pop, Oct. 15, A. D. 1209.	
11-12- 8-13- 4	6 Kan	2 Pop, Oct. 16, A. D. 1209.	Year-bearer.

UXMAL, BALL COURT RINGS:

11-15-16-12-11, 10 Ix $\begin{cases}\text{16 Pop, Oct. 14, A. D. 1276.}\\ \text{17 Pop, Oct. 15, A. D. 1276.}\end{cases}$

This inscription documents calendar change to Mexican style.

TOLTEC ERA:

Year 1 Tecpatl, Day 1 Tecpatl	Aug. 6, 1168 A. D.
Baktun 7, Maya Era 11	Aug. 6, 613 B. C.
Difference in tropical years	1781

This is Mexican date of emergence from the Seven Caves.

TOLTEC SCHISM:

11–10–16–11– 3, 2 Akbal 1 Yaxkin Feb. 21, A. D. 1178.

Chumayel date for institution of human sacrifice by Toltec opponents of Nacxitl Quetzalcoatl.

TOLTEC NEW FIRE CEREMONY:

11–11–14–15–13, 7 Ben 1 Yaxkin Feb. 17, A. D. 1196.

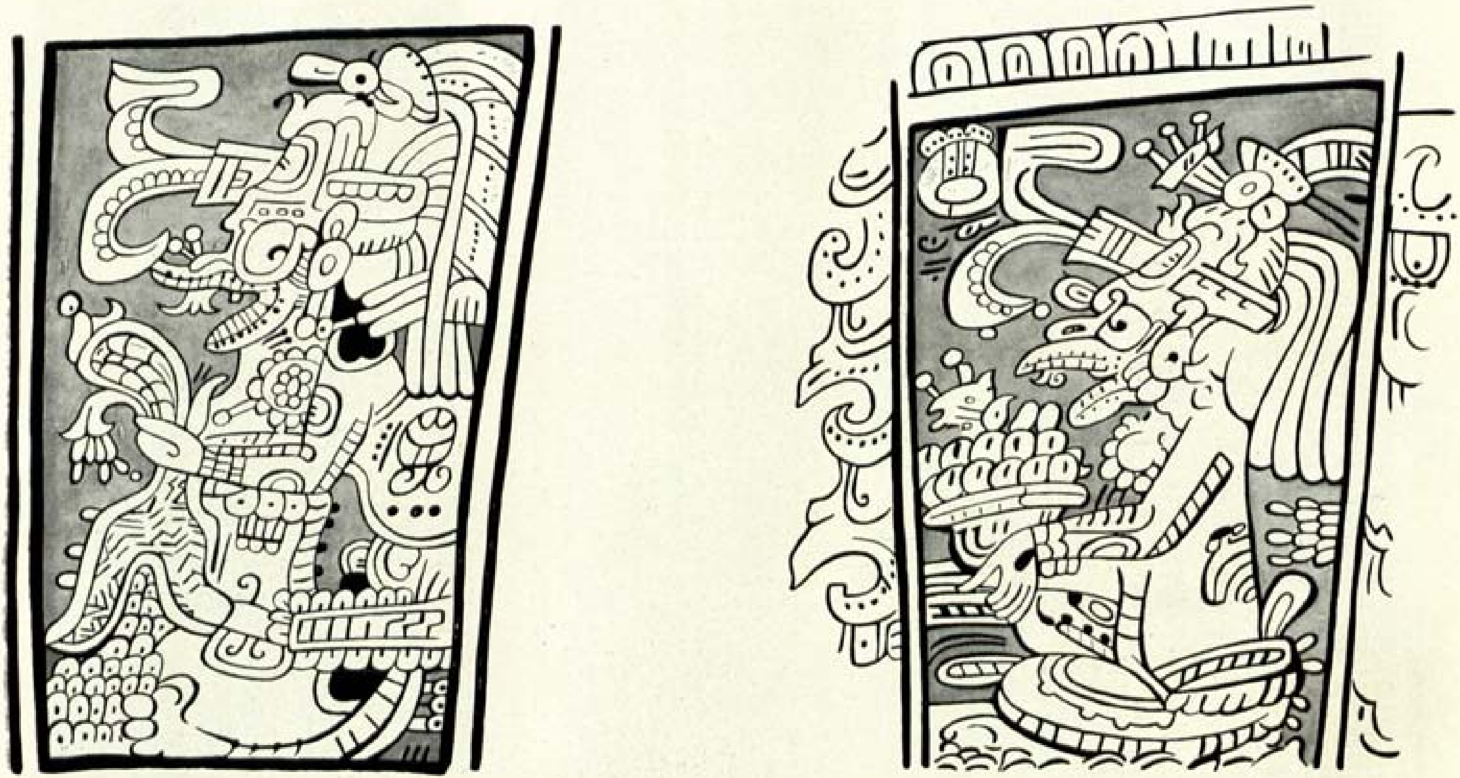
The last two dates concern the New Fire Ceremony, originally a Quetzalcoatl feast celebrated with feather banners. It was stolen by his Tezcatlipoca opponents: Panquetzaliztli is the corresponding Mexican feast.

STEP OF THE MIDDLE DOORWAY, STRUCTURE 44, YAXCHILAN

The dates of this temple handle the tropical year. The bottom panel shows the sun and a jaguar sun god inside; below this is the owl of Maya zero; to the left of the sun is the front head of the sky monster, the rear one occupying the lower right-hand corner of the panel. In the lower right-hand corner is the moon containing a rabbit.

TEMPLE AT DZIBILNOCAC

Building of the Intermediate Period now dated by painted capstone as dedicated in A. D. 934.



PAINTED CAPSTONE, TEMPLE OF TWO TOWERS, DZIBILNOCAC

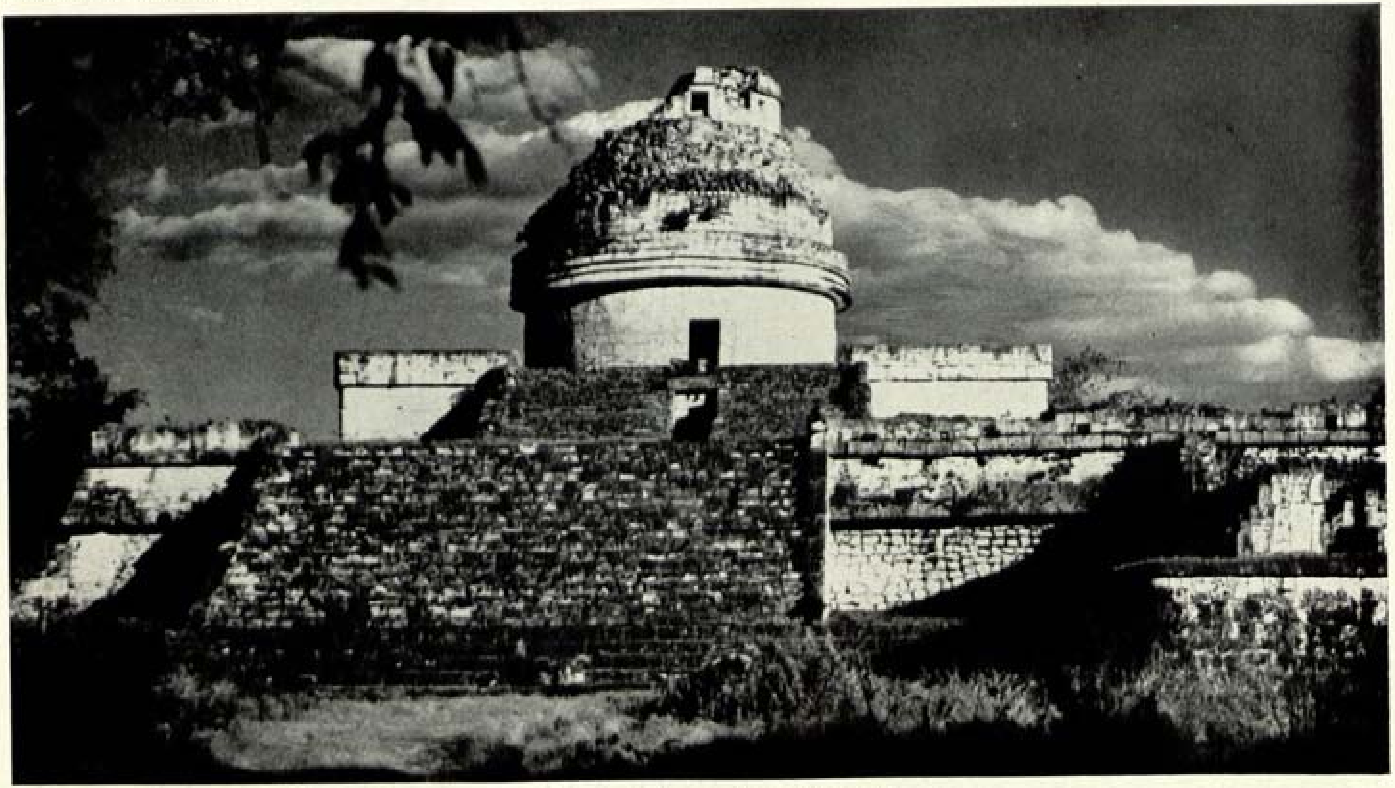
Year-bearer 3 Kan in Tun 9. Grand rounds of solar and Venus calendars: First, O Pop at winter solstice, 576 B. C. and A. D. 933. Second, Venus at heliacal rising November 29, 572 B. C. and A. D. 934. Venus calendar A of Dresden Codex inaugurated.

1. THE HOUSE OF THE MAGICIAN AT UXMAL, WESTERN FACE

Although apparently in ruinous condition, good data exist for the reconstruction of this composite edifice.

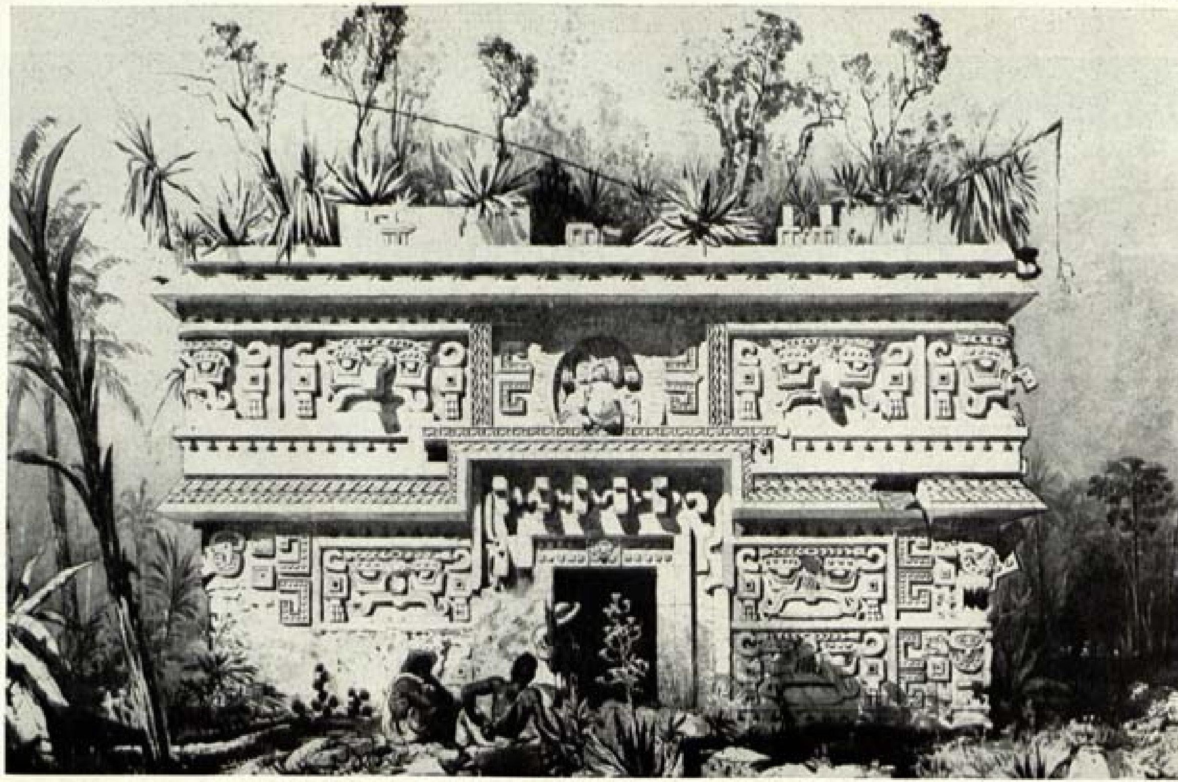
2. HOUSE OF THE MAGICIAN AS RESTORED IN A MODEL IN THE BROOKLYN MUSEUM

The earliest building with its pyramidal substructure is completely enclosed by three later ones. On the ground level is the second phase, a long building completely covered with Venus masks. The third stage is represented by an elaborate stairway leading up to an ornate temple. The enlarged pyramid is crowned by the fourth building.



THE SNAIL, CHICHEN ITZA, YUCATAN

Astronomical observatory and memorial to Nacxitl Quetzalcoatl. Date on building is April 4, A. D. 1280, seventy-second anniversary of Quetzalcoatl's death. Dates on inscribed monument in stairway deal with ancient Venus phenomenon (inferior conjunction at Baktun 10) and anniversaries of Maya eras.



CATHERWOOD'S DRAWING OF EASTERN FACADE OF NUNNERY, CHICHEN ITZA

Naexitl Quetzalcoatl enthroned as Venus god above celestial band with planet Venus in conjunction with zodiacal constellations. This memorial perhaps dedicated on fourth octennial, heliacal rising April 5, A. D. 1240, Venus date common in Mixtec codices.

THE NATIONAL STONE FOUND IN MEXICO CITY

This may illustrate how the Calendar Stone was set up. The Olin sign in the center of this and other Aztec suns represents a year dial: Olin means movement. One rabbit and two reeds are the years A. D. 1507 and 1508.

Surviving Indian Groups of the Eastern United States

By WILLIAM HARLEN GILBERT, Jr., *Library of Congress, Washington, D. C.*

Introduction

The following paper was prepared for the purpose of indicating the extent to which Indian blood still remains noticeable in our eastern States population in spite of the depletions arising from over 300 years of wars, invasions by disease and by white men from Europe and black men from Africa. Any attempt to estimate the total amount of this Indian and mixed population must be based on an arbitrary classification of mixed-bloods as Indian who may frequently be more white or Negro in appearance. Anywhere from 75,000 to 100,000 persons may be included in the groups described in the following pages.

The census returns of "blood purity" are of course not to be taken as in any way biologically accurate. These figures are much better used as indications of the character of local opinion, Throughout the following discussion the term "blood" is to be understood as relating to opinion and not to actual biological fact.

It will be noted that not all the Indian mixed groups have kept their original tribal names because in a considerable number of cases the only distinguishing terms are nicknames given them by white people. Where the native Indian speech is retained, some notice of the fact is given. In the same way the survival of other Indian customs and traits is noticed as additional evidence that Indian blood may survive.

The material in the following discussion is presented by States in geographic order, beginning with the northernmost part of the Atlantic seaboard and ranging down to Florida, thence across the Gulf coast to Texas, and finally concluding with some comments on certain midwestern States. In each State an effort is made to note the evidence for Indian survivals especially through cases of separate social groups found claiming an Indian descent. It will be noticed that the census figures are often below the unofficial estimates of these population remnants. All too often the census ignores their existence. The 1930 census figures have been used in this discussion since they give the tribal break-down, whereas the 1940 census does not.

1. *Maine*

According to the census, the Indian population of Maine totaled 1,012 in 1930. Of these, 76 were in Aroostook County on the northern borders (Malecite Tribe), 444 were in Washington County on the eastern border (Passamaquoddy Tribe), and 354 were in Penobscot County in the central part of the State (Penobscot Tribe). of the total, full-bloods were 46.3 percent, mixed-bloods 42.4 percent, and not recorded 11.3 percent.

Penobscot.—The Penobscot Tribe retains ownership of a number of islands in the Penobscot River from the falls at Old Town north to Mattawamkeag.

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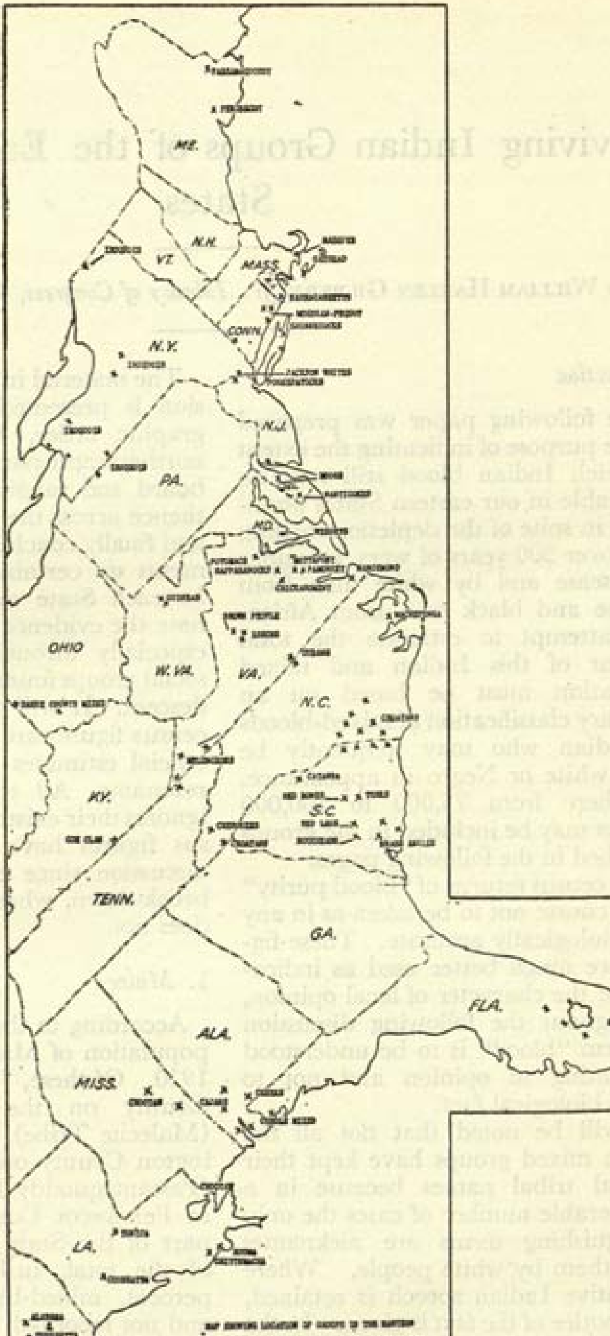

FIGURE 1.—Map showing location of groups in the eastern States of Indian and part Indian descent, 1946.

These islands total around 4,481 acres and the land is under family allotment. The State has encouraged agriculture by payments in past years, but the Indians are reluctant to engage in it. The principal settlements are at Old Town on Indian Island, some 12 miles north of Bangor, and on Old Lennon and Lincoln Islands. In 1915 the Penobscot totaled 22 families, and in 1939 there were 580 persons in the tribe. Considerable intermixture has taken place with the other two Indian tribes of Maine, the Passamaquoddy and Malecite.

The Penobscot have a tribal government of their own, which is subject to the State of Maine, but have no Federal relationship. There are two political parties among these people, the Old Party and the New Party, each of which has an alternate term of 2 years in power with its own governor, lieutenant governor, representative to the State legislature, constable, council members, and minor officials.

Passamaquoddy.—This tribe, residing mainly on the south side of Passamaquoddy Bay and on nearby Lewis Island, now numbers around 500 members. Their principal settlement is at Point Pleasant and there is another near Princeton (in Princeton Township) to the north of the first. They also have their own tribal government and representative in the State legislature.

Both the Penobscot and Passamaquoddy are mostly Roman Catholics, and the two Indian schools at Point Pleasant and Old Town have teachers supplied by the church, while the financial support is supplied by the State. Health conditions are good in both tribes, and where necessary the State provides payment for physician's care. Basketmaking, gardening, and poultry raising are prominent industries. The Algonkian Indian speech is retained by these two major tribes.

2. *New Hampshire*

No important surviving social groups of Indians are recorded for New Hampshire. There are a few Pennacook Indians near Manchester, however.

3. *Vermont*

No surviving social groups of Indians are recorded for Vermont, although the census records a few scattered individuals.

4. *Massachusetts*

In 1930 the census recorded 874 Indians in Massachusetts, 356 in Barnstable County (Cape Cod), 178 in Bristol County (along the eastern border of Rhode Island), and 83 in Worcester County (in the east-central part of the State). The Cape Cod Indians are centered at Mashpee, Yarmouth, and Waquoit, while those in Bristol are near Fall River. At Gay Head, the westernmost part of Martha's Vineyard Island (Dukes County), there is a considerable group of pottery-making Indians (178 in 1930), mainly Wampanoags. In Plymouth County there are Indians at Assawompset Pond, while in Norfolk County there is a group located at Canton.

Only 2.5 percent of Massachusetts Indians are reported as full-bloods and the rest are mixed with white blood and to a great extent with Negro blood, and with the Portuguese "Bravas." These Indians are Baptists, attend public schools, and only 2.3 percent of those 10 years old or over were returned as illiterate in the 1930 census.

Two groups that stand out among the Massachusetts Indians are the Mashpee and the Nipmuc. The Mashpee live by fishing, making and selling of baskets, oystering, and cranberry picking. Like the Indians of Gay Head they are an organized "tribe" with an elected chief.

The Hassanamisco Band of Nipmuc are still to be found scattered in various towns of central Massachusetts (Grafton, Worcester, Boston, Gardner, and Mendon), and there are a few at Mystic, Conn., and Blackstone, R. I. The present-day family names of this group are Barber, Belden, Brown, Cisco or Sisco, Curliss, Gidger or Gigger, Gimbey, Hamilton, Hector, Heminway, Lewis, Moore, Peters, Scott, Tony, and Williams. The Nipmuc still cling tenaciously to their Indian identity and are set apart from Whites of the underprivileged class and also from mulattoes and Negroes. Apart from their traditions there is nothing in their manner of life which would set them apart. They are employed in skilled crafts and industries and in government offices.

5. *Rhode Island*

The census for 1930 records 318 Indians in Rhode Island, 170 in Washington County (along the southern coast near Kingston), and 138 in Providence County (in the northern parts of the State). Of the total, 19.5 percent were recorded as pure-bloods, 13.2 percent as mixed-bloods, while 67.3 percent were not recorded. There is said to be considerable mixture with both white and Negro blood, the lighter-skinned holding aloof from the darker group. These people attend the public schools, and about 2 percent of those 10 years old and over are recorded as illiterate. As in the case of the Massachusetts Indians, most of the Indian traditions and customs are lost, including the native speech. The Narragansett Association was incorporated under charter from the State in 1935 to include all tribesmen and now claims around 260 members. The dark mixed-bloods are said to have their own organization.

6. *Connecticut*

In 1930 the total number of Indians recorded for Connecticut by the census was 162. These were mostly scattered in a few settlements along the sea coast and inland in New London County. The largest concentration is in the Groton area near the town of New London, where the Mohegan and Pequot tribesmen still survive.

There are about 75 members of the Pequot Tribe located on two State reservations at Ledyard Town and Stonington Town in New London County. These groups own their own lands. A distinct tribe are the Mohegans who are located on the west bank of the Thames River 4 miles east of Norwich at the village of Mohegan and at Mohegan Hill. The Schaghticoke are a small handful of families located in Fairfield County on the western border of the State where the Housatonic bends westward almost to the New York border. There is a small group of Indians at Niantic, west of the town of New London, and a similar small group on land of the Paugusetts near Bridgeport. All these various groups are under the State of Connecticut Park and Forest Commission. Some survivals of Indian arts are to be found such as basketry, woodcarving, beadwork, and nature lore, especially among the Mohegan and Pequot.

The census reports 9.3 percent of Connecticut Indians as full-bloods, 30.2 percent as mixed, and 60.5 percent as not recorded. As in Rhode Island and Massachusetts, there has been mixture with both white and Negro blood, and Indian traditions and speech have been almost entirely lost. About 2 percent of those 10 years of age and over were reported as illiterate in 1930. When the Mohegan Association was formed by a State charter in 1920 to include all tribesmen, a total of 122 members were claimed.

7. *New York*

A total of 6,973 Indians was recorded for New York State in 1930. The majority of these were Iroquois tribesmen concentrated up-State on reservations in northern, central, and western New

York. There were also a few other tribes of Indians located at certain points in eastern Long Island. In Orange and Rockland Counties, on the borders of New Jersey, are the Jackson Whites, a mountain people with a strongly marked Indian background. The latter are not included as Indians in the census reports, however. In 1930 some 11.6 percent of New York Indians 10 years old or over were illiterate.

Iroquois.—The Iroquois Indians of New York are mainly located on six reservations, namely, Cattaraugus, Allegany, Tuscarora, Tonawanda, Onondaga, and St. Regis. On these reservations they have retained to a remarkable degree their native speech, their native religion, and many aboriginal customs and traditions. There has been considerable admixture of white blood with these Indians. The census of 1930 reported 4,365 members of this group, 36.1 percent fullblood, 62.8 percent mixed-blood, and 1.1 percent not recorded.

The Cattaraugus Indian Reservation includes some 21,760 acres in Erie, Chautauqua, and Cattaraugus Counties, from the mouth of Cattaraugus Creek on Lake Erie to a point 10 or 12 miles from the mouth. Here live 2,000 Indians, mainly Senecas with a few Cayugas and Onondagas. They are steel workers, mechanics, farmers, trappers, and fishermen, and they lease some of their land to white market gardeners and to operators of gas wells. The Federal Government pays these Indians an annual treaty stipend. Flowers, sassafras, baskets, beads, and handiwork items are sold in the nearby cities. The Longhouse people of Newton keep up the annual cycle of thanksgiving festivals, being followers of Handsome Lake, the Seneca prophet (1750?–1815). Methodists and Baptists have long maintained missions here.

Along the Pennsylvania border in Cattaraugus County is located the Allegany Indian Reservation. This domain extends along both sides of the Allegheny River from the point where it enters Pennsylvania, in a long thin arc for 30 miles, and comprises 26,880 acres. This reservation borders the northern edge of Allegany State Park and adjoins the Cornplanter Reservation in Pennsylvania. A number of white communities are found within the bounds of this reservation, including the city of Salamanca, and whites hold the land on long-term leases. There are about 900 Senecas, of whom at least half speak Seneca, and a scattering of Cayugas living on small farms. The State appoints an attorney to guard the legal interests of these Indians under the Federal New York Indian Agency with superintendents in Buffalo. The Longhouse religion predominates, but Presbyterian and Baptist missions have been maintained here. Near the Allegany Reservation are some 640 acres of land owned by the Senecas in Allegany County at Oil Springs (near Cuba, N. Y.), which are leased to whites.

The Tuscarora Indian Reservation is located in Niagara County about 4 or 5 miles to the northeast of Niagara Falls, N. Y. This area comprises about 6,249 acres and has some 430 Tuscaroras living on it as farmers. There is a community house, a Baptist church, a school, and the State furnishes visiting supervisors. These Indians are all Christians but still retain their old-time language, council, and many old tribal laws. They are under the New York Indian Agency at Buffalo.

The Tonawanda Indian Reservation comprises 7,549 acres in Erie and Genesee Counties along Tonawanda Creek, 20 miles northeast of Buffalo, N. Y. On this reservation live about 600 Senecas of the Tonawanda Band of whom a third at least are Longhouse followers. Life chiefs govern through council. There are Baptist and Methodist missions among these people and the State Department of Public Welfare maintains a community house. Over half speak or understand Seneca. These Indians find employment in

the gypsum plants of nearby Akron, N. Y., and also work on the roads and on nearby farms, and in Buffalo factories. A New York State attorney at Batavia represents them, and they come under New York Federal Agency.

In Onondaga County a few miles south of the center of Syracuse, N. Y., is located the Onondaga Indian Reservation, a tract of 6,100 acres, valley and highland. Here live 700 Onondaga Indians along with some 200 Oneidas, Cayugas, and other Indians. Onondaga is still spoken. Less than 100 of the Onondagas are said to be full-bloods. Rental is paid by white men for use of sand, stone quarries, and pipe lines. There are three churches, a public school, two council houses, and an office of the State department of health. One council house is used by the Longhouse group, who adhere to the Code of Handsome Lake and constitute about 30 percent of the total, the other by the Christian Indians. A council of life chiefs governs the tribe. Episcopalians and Methodists have maintained mission work here. Many of the Onondagas find employment in Syracuse factories and homes. About 30 miles eastward there are a few Oneidas settled on some 30 acres outside of Oneida, N. Y.

St. Regis Indian Reservation is located on the Canadian border in Franklin and Lawrence Counties where the New York line reaches the St. Lawrence River. It comprises 16,640 acres, and is 9 miles long by 3 miles wide. Part of the St. Regis Reservation is on the Canadian side. There are 2,800 Indians here, mostly Mohawks. Of the entire group 100 are full-bloods, whereas the rest are mixed with white blood. These Indians are governed by three elected chiefs (a minority adhere to the life-chief system) and as wards of the State pay no taxes and receive free medical care and schooling. Some are makers of baskets and moccasins, but the majority are dairy farmers, steel workers, and lumbermen. Both Methodist Episcopal and Roman Catholic mission workers have labored among these people, and none of them are pagans. They are under New York Federal Indian Agency at Buffalo. The Mohawk language is still spoken.

At Lake George, in the northeast of the State, there is a small band of Abenaki Indians.

Long Island Indians.—In eastern Long Island there are five remnants of Algonquian Indian groups, namely, the Shinnecock, the Poosepatuck, Montauk, Setauket, and Matinecock. The Indians in Suffolk County totaled about 266 according to the 1940 census. The Shinnecock are located on Shinnecock Bay near Southampton, N. Y. They occupy about 50 acres on a neck of land running out into the Bay and number about 150 persons, have a Presbyterian church, lease for cultivation about one-tenth of the land, do fishing, hunting, and clamming, and have lost most of their Indian culture, being much mixed with whites and Negroes. Their land is tax free, and they are governed by three trustees elected annually. The Shinnecock do beadwork and make a kind of brush for scouring pans. Their family names are Arch, Beaman, Bunn, Cuffee, Davis, Harvey, Kellis, Scudder, and Thompson.

The Poosepatuck occupy 50 acres near the mouth of the Mastic River about 15 miles west of the Shinnecock and are in the southern part of the town of Brookhaven. They have three trustees elected annually to manage their affairs, and have their own church and State-supported school. They have held this land since 1693 and now number about 10 families.

The Montauk have two settlements located on Montauk Point about 40 miles east of the Shinnecocks. Like the latter and the Poosepatuck they are largely mixed with white and Negro blood and have lost most of the Indian culture.

The Matinecock are a few Indians located near Cold Spring by Long Island Sound in Nassau County. The

Setauket are a remnant located between Stony Brook and Wading River in Suffolk County.

Other New York mixed-bloods.—Along the banks of the Hudson River in New York State the country is well developed and modern in every respect. But on the upper edges of the hills whose slopes can be seen from the river live a border people, independent, primitive, and often of Indian mixed blood. They make a living of sorts by scanty cultivation, by fishing, by hunting, and by basketmaking. North of Albany in Rensselaer County these people are known as Van Guilders. In Columbia County live the "Bushwhackers," whose chief family names are Hotaling, Simmons, and Proper. These are also known as "Pondshiners." To the west of the Hudson, from Newburgh southward, are other Bushwhackers. Those east of the Hudson are Indian and white, those to the west partly Negro.

Estabrook and Davenport in 1912 described a group of Indian mixed-bloods, under the pseudonym of "Nams," who were living in up-State New York. They characterized this group as alcoholics, ambitionless, and defective in both physical and mental inheritance. According to tradition they were descended from the issue of a Dutchman and an Indian "princess" some time before 1760 in western Massachusetts. These people, half vagabonds, half fishermen and hunters, left Massachusetts in 1800 and settled in New York State. The famous "Jukes," a group first described by Dugdale in the nineteenth century, were also an up-State New York group of mixed Indian and other descent.

In the Schoharie Valley, not far to the west of Albany, there are a number of isolated or submerged groups who seem to be of Indian mixed-blood descent. Such are the Slaughters of Slaughter Hill, a clan supposedly descended from a governor of Colonial times, the Honies of the southern part of Schoharie County, the Clappers of Clapper Hollow, and the "Arabs" of Summit. The Slaughters spend the summertime in berry picking, hunting, and fishing.

Jackson Whites.—These people are located in an area roughly extending from Goshen to Nyack along the New Jersey borders in Orange and Rockland Counties. In some parts they show a predominance of Indian physical characteristics and in others of white or a mixture of white and Negro. The Indian blood is said to be derived from the Tuscarora and Munsee tribes, but the traditions and customs of the Indian are now difficult to find. A Negro Presbyterian church at Hillburn, N. Y., has carried on mission work among the Jackson Whites. The total number of these people in both New York and New Jersey is estimated at 5,000. Some of the principal family names among them are Cassalony, Cisco, De Groat, De Vries, Mann, and Van Dunk. Living on the margins of society, as they have been forced to do, the Jackson Whites have been a somewhat neglected class of people.

Some of the Jackson Whites have migrated to the industrial areas and the cities. Likewise some of the St. Regis Mohawks of up-State New York have taken up occupations such as ironwork and structural steel erection and have migrated to Brooklyn to form a colony there.

In Brooklyn there is an area called "the Gowanus District" which includes parts of Nevins Street, Atlantic Avenue, Pacific Street, and Schermerhorn Street. In this area there is at present a settlement of over 500 Indians, representatives of about 17 different tribes. Primary in importance among this group are the Mohawks already referred to, steel workers and welders from up-State New York.

8. *New Jersey*

In 1930 the census reported 213 Indians in New Jersey, mainly located in Essex County (Newark). However, there were several groups of mixed-bloods not listed as Indians, such as

the Jackson Whites of the northern counties, the Pineys of the central pine barrens, and the Moors and Gouldtown people of Cumberland County in the southern part of the State.

Near Eaton Town in Monmouth County, N. J., a band of Indians settled before the Revolutionary War. They were supposedly descended from Tuscarora or Cherokee migrants from North Carolina. At a somewhat later date they located at Asbury Park upon a site called Sand Hill. They came to be known as the Sand Hill Indians of Monmouth County and their home was called "The Reservation" or "Richardson Heights" after the name of one of their prominent members. Within the last 30 years the members of this group have largely scattered to other locations. Indian traditions and arts have survived among this group until the present time. Beadwork and basketry have been made in recent years.

Jackson Whites.—As already noted, the Jackson Whites totaling 5,000 or more, are scattered over parts of New York and New Jersey. As such they form an interstate population. They are a mixed-blood group, descendants of white, Indian, and in some areas Negro ancestors. They live by cultivation of the hillsides with a patch of corn or potatoes here and there, by hunting, and by keeping a few pigs, chickens, and now and then a cow. They are mainly located in the Ramapo Valley and the adjoining hills in Passaic, Bergen, and Morris Counties along the northern border. Wherever possible they are encouraged to enter local public schools. Split basketry and carved wooden utensils are manufactured as domestic industries.

Pineys.—The Pineys in Burlington and adjacent counties are partly pure-blooded whites in some sections and mixed-bloods in others. At New Lisbon, about 25 miles directly east of Philadelphia, the colored or mixed-blood Pineys are most prominent, and these are said to contain a considerable contingent of Indian blood. Not far to the south of New Lisbon was the site of the last Indian reservation in New Jersey. The number of the Pineys has been estimated at 5,000.

Like the Jackson Whites, the Pineys are a neglected group who make a living by cranberry picking, weaving baskets, manufacturing ax handles, trapping, bootlegging, and doing odd jobs for nearby farmers. A few raise chickens and vegetables for home consumption. Like the Jackson Whites and certain Indian groups in southern New England, the asserted presence of Hessian blood may be a factor in stigmatizing these people.

Moors.—Around Bridgeton in Cumberland County, southern New Jersey, is a colony of the so-called Moors who seem to have come from central Delaware across Delaware Bay. These people appear to have Indian, Negro, and white antecedents and will be mentioned in more detail in the section on Delaware. Like the Jackson Whites, they constitute a part-Indian unorganized division of the population who are differentiated from their white and Negro neighbors. Also similarly to the Jackson Whites, they constitute an interstate population.

Near Bridgeton is a settlement called Gouldtown which is inhabited by a mixed people like the Moors but who seem to be of separate origin from them. The Gouldtown people have been regarded as light mulattoes by their neighbors.

9. *Pennsylvania*

The Seneca Indians of the Cornplanter Reservation in Warren County present an interstate Indian population just as the Jackson Whites do farther east. The Cornplanter area is close to the Allegany Reservation just over the line in New York State. There are about 30 Senecas and a few Onondagas living on the 800 acres of the Cornplanter Reservation. According to the 1930 census, of Pennsylvania's 523 Indians, 40 percent were pure-bloods, 29 percent

mixed, and 31 percent not recorded. Practically all these Indians are Christians, and there is a Presbyterian church and a school. Seneca is spoken by the old people.

The census records a few Indians in certain other counties of Pennsylvania, in Alleghany (Pittsburgh), in Bucks (North Philadelphia), and in Philadelphia. The Indians of Philadelphia have their own association.

"*The Pool Tribe.*"—In and about Towanda, Pa., and in various parts of Bradford County there is a submerged group which is referred to locally as "The Pool Tribe." There are over 500 members of this inbred group whose chief family names are Van der Pool, Johnson, Vincent, Heeman, and Wheeler. They are farm laborers, and a large section have the reputation of being subnormal and addicted to petty crime. Traditionally they are descended from Sir William Johnson who in 1744 left over 100 half-breed children by women of the Oneida, Mohawk, and other tribes.

Cherokees.—There is a small group of Indians, apparently of Cherokee descent, residing in the mountains near Harrisburg. Traditionally they are descended from a group of Cherokees who went northward with the Tuscarora in 1710 and stopped in the Cumberland Valley of Pennsylvania. They then took up homesteads in the Blue Mountains from Doublin Gap to directly north of Chambersburg. Since the papers and land titles of this group were burned recently during a quarrel between factions, the neighboring whites have been said to be "moving in" on the lands of these Indians.

10. *Delaware*

There are two groups in Delaware who are probably of part-Indian origin, the Moors of Kent County in the central part of the State and the Nanticokes of Sussex County in the southern part of the State. The census does not return either of these groups as Indians, and no official data are gathered regarding them.

Moors.—This group, which here numbers about 500 persons according to private investigators, is located mainly around Cheswold, about 5 or 6 miles north of Dover, the State capital. As we have already noted, there is another colony of these people in southern New Jersey at Bridgeton. They show a variety of physical traits and vary as to complexion from rather blond to very dark. It is thought that they may represent a cross of some dark race (not necessarily Negro) with Indians and whites. In common with the Nanticokes farther south, they are farmers, fishermen, carpenters, truck drivers, poultry raisers, storekeepers, gas station attendants, and common laborers. Unlike the Nanticokes, however, they have not organized themselves in a corporation for mutual betterment. They have their own churches, a Methodist and an Adventist group being represented, and seem to segregate in particular elementary schools. There is no provision for high schools for them locally, and they would have to attend Negro schools for this level of education.

Moors are characterized by certain family names, the principal ones being Carney, Carver, Coker, Dean, Durham, Hansley, Hughes, Morgan, Mosley, Munsee, Reed, Ridgeway, Sammons, and Seeney. Some of these names are shared by the Nanticokes.

Nanticokes.—The Nanticokes are located primarily around Millsboro on Indian River, but their settlements are somewhat scattered in the nearby area. They present more of the physical characteristics of the Indian than do the Moors and seem to have divided themselves socially into two groups, a darker group called the Harmony Group and a lighter group who cling to the name "Nanticoke" Indian. Altogether both groups are said to total about 700 people. First incorporated under State laws in 1881, they were reorganized and reincorporated in 1921 as the Nanticoke

Indian Association. They are Methodists in the main and have their own churches.

The chief Nanticoke family names are Bumberry, Burke, Burton, Clark, Cormeans, Coursey, Davis, Drain, Hansor, Harmon, Hill, Jackson, Johnson, Kimmey, Layton, Miller, Morris, Moseley, Newton, Norwood, Reed, Ridgeway, Rogers, Sockum, Street, Thomas, Thompson, Walker, and Wright. They have separate schools from whites, and to some of these schools Negroes are admitted. They are required to attend Negro high schools, if any. Many have obtained a higher education in spite of segregation. Most of the Indian customs are lost.

11. *Maryland*

The census does not recognize any Indians in Maryland, just as in the cases of Delaware and New Jersey, yet there is a fairly large-size group called the Wesorts in southern Maryland, in Charles and Prince Georges Counties, who claim a part-Indian descent. In addition there are certain small groups of "Nanticokes" on the eastern shore in Dorchester County and vicinity, and a few very small groups in the Blue Ridge area on the borders of Frederick and Washington Counties.

Wesorts.—The Wesorts are scattered in rural areas about Bel Alton and Port Tobacco in Charles County, and at Brandywine, Upper Marlboro, and Oxon Hill in Prince Georges County. They are tenant farmers and truck farmers on the borders of Washington. Many have settled in Washington, Pittsburgh, and other cities as artisans, salvagers, and small tradesmen. Their total numbers are estimated as upward of 5,000.

These people show physical traits reminiscent of whites, Indians, and Negroes. Some of them carry traditions and a few customs which may be of Indian origin. Locally they are considered in the same status as mulattoes and their children are required to attend Negro schools. They are Roman Catholics and generally tend to sit with or near the colored sections in churches. Although thrown into constant contact with Negroes they have mainly married only within their own group. They are characterized by these family names: Butler, Harley, Linkin, Mason, Newman, Proctor, Queen, Savoy, Swan, and Thompson. In spite of the fact that they have never organized themselves as a distinct minority, they have been recognized in parish and county records as separate from the Negro. They have a high birth rate.

12. *West Virginia*

As in previous cases mentioned, the census does not recognize any Indian groups in West Virginia. However, there is a fair-size group of people centering in northern Barbour and southern Taylor Counties in the northeastern part of the State who may lay claim to at least part-Indian ancestry. These are the "Guineas" whose numbers may range up to 6,000 or 7,000. Small groups of these people are to be found in six or seven other counties in northern West Virginia, in parts of western Maryland, in cities of eastern and northern Ohio (such as Zanesville) and in Detroit.

The Guineas present the usual variety found in mixed-bloods, but the white and Indian seem to be most prominent. They have their own Methodist churches and attend segregated schools which are locally classed as "colored." As a class they stay apart from both whites and Negroes and are characterized by the following family names: Adams, Collins, Croston, Dalton, Kennedy, Mayle, Newman, Norris, and Prichard. Their racial classification has furnished considerable difficulty to the local authorities.

13. *Virginia*

The census of 1930 records only 771 Indians in Virginia, mostly in the Tidewater area, such as Pamunkey,

Chickahominy, Rappahannock, and others. Of this total 19.3 percent are recorded as full-bloods, 53 percent as mixed-bloods; 27.7 percent are recorded as illiterate.

There are two schools of thought in Virginia regarding the mixture of blood in the Tidewater Indian tribes. One school holds that all, or practically all, the members of these tribes are mixed in some degree with the Negro. This opinion requires that birth certificates, marriage licenses, and military draft papers of the Indians take note of their classification as Negro and obliges public officers to treat them accordingly. This school of thought has been in the dominant position in the State administration.

The other school, apparently in the minority, holds that most of the Tidewater Indian groups have little or no Negro mixture in their blood and that they should be recognized as Indians or as Indian-white half-breeds. Evidently no accurate opinion can be rendered on the subject until a scientific investigation is made by physical anthropologists.

Chickahominy.—This tribe is divided into two sections: (1) the Upper Chickahominy who reside principally in Charles City County at White Oak Swamp on the Chickahominy River near Roxbury, Va., and number about 357; (2) the Lower Chickahominy who live on the lower Chickahominy River on the Chesapeake and Ohio Railroad between Newport News and Richmond, in the neighborhood of Boulevard, Va. The latter group is about 55 miles from Newport News and 40 miles from Richmond. They number about 100 persons, and are situated in James City County. Both of these groups have intermarried with the Pamunkey Indians, their near neighbors to the north. The main Chickahominy family names are Adkins, Bradby, Colman, Holmes, Jefferson, Jones, Miles, Stuart, Swett, Thompson, and Wynne.

The people of this tribe live by fishing and hunting in the river swamps and by cultivating patches on the nearby higher land. They were reorganized in 1908 as a tribe with a chief and other officials but have had no specially recognized reservation of long standing as have the Pamunkey and the Mattapony.

Pamunkey.—This group resides on a State reservation of about 800 acres in King William County at a bend of the Pamunkey River. They are hardly more than 20 miles due east of Richmond, the State capital. There are about 150 Pamunkey on the reservation with about 150 more scattered elsewhere. They derive a living by fishing, bird catching, and by cultivating their fields of corn and beans with the help of hired Negro labor. This reservation has been in existence since 1677. The Pamunkey neither vote nor pay taxes but are governed by an elected chief and council subject to supervision by trustees appointed by the State. The main family names current among these people are Bradby, Collins, Cook, Dennis, Hawkes, Holmes, Langston, Miles, Page, Sampson, and Swett. They are mostly Baptists. The Indian blood of the Pamunkey is variously estimated at from one-fifth to three-fourths.

Mattapony.—The next tribe to the north of the Pamunkey is the Mattapony. Like the Chickahominy the Mattapony are divided into two groups, both in King William County: (1) the Lower Mattapony group is located on a State reservation of 50 acres situated on a bend of the Mattapony River not over 10 miles north of the Pamunkey; (2) the Upper Mattapony or Adamstown Indians, live about 20 miles west of the first group and about 38 miles northeast of Richmond (near Central Garage).

The Lower Mattapony number about 150 persons, the Upper group about 170. Both live by lumbering and farming. The chief family names in the Lower group are Allmond, Collins, Costello, Langston, Major, Reid, and Tuppin; in the Upper group Adams, and Holmes. The Lower

group has been organized as a reservation since 1658, whereas the Upper Mattapony have only been organized since 1923.

Rappahannock.—To the north of the Mattapony are the Rappahannock who are rather widely scattered in the area to the south of the Rappahannock River in Caroline, Essex, and Upper King and Queen Counties. They are centered especially around Indian Neck, Va., and are estimated to number from 400 to 500 persons. This group was incorporated under State law as The Rappahannock Indian Association in 1919. They are unlike the previous groups mentioned in the great amount of dispersion which they have undergone as small bands. The area inhabited extends roughly about 15 miles south and west, about 25 miles north and south, and in this section the whites constitute not more than a third of the population.

The Rappahannock are fishers, farmers, hunters, and some are expert basketmakers. They are undoubtedly a mixed group with a varying percentage of Indian blood. A band in Upper Essex County has Nelson as the most common family name.

Miscellaneous Tidewater Indians.—In addition to the important groups just mentioned there are a number of other Indian remnants in the Tidewater of Virginia. The Potomac Indians, for example, are a small band of 150 to 200 persons situated in Stafford County about 8 miles due north of Fredericksburg, Va., on a small branch of the Potomac River. They engage in farming and fishing, and their members appear on back roads of Prince Wliliam and Fairfax Counties right up to Alexandria, across from Washington, D. C.

There are also Indian groups in Northumberland County at the mouth of the Potomac River estimated to number around 300 persons. These are thought to be the remnant of the Wicomico Tribe of Colonial times.

Across the Chesapeake Bay on Virginia's eastern shore there are still to be found remnants of the Accohannock Tribe among the colored populations of Accomac and Northampton Counties. The number of these mixed folk is unknown, but they are said to be located at Accomac County Courthouse (Drummondtown) and near Fisher's Inlet in southern Northampton County. In the latter place they bear the family name of Miles.

Along the shores of the York River are also to be found small Indian remnants. A band in York County, on the south shore of the river to the northwest of Hampton, have the family name of Wise. On the opposite or north shore of the York River are certain small groups centering in Allmondsville and Gloucester Point in Gloucester County. The Gloucester County groups are said to number about 100 persons. At Allmondsville the family names are Allmond, Norris, and Langston, while those at Gloucester Point are Sampsons. The Gloucester County groups are thought to be remnants of the Werowocomoco Tribe of Colonial times. In the eastern part of Gloucester County is an area called Guinea Neck once inhabited by people called Guineamen who may have had an Indian connection.

Crossing over the James River to the southern shore one finds remnants of the Nansemond Tribe in Norfolk and Nansemond Counties. Their chief center is at Deep Creek in Norfolk County not far to the southwest of Norfolk, Va. Located on the northern and eastern edges of the Great Dismal Swamp they number about 200 souls dispersed rather widely. They are widely mixed and have a large number of family names. The principal names originally were Boss and Weaver. They are truck farmers, and ship produce to Norfolk commission houses. The Nansemond have been reorganized as a tribe since 1923. Allied to these may be the Skeetertown Indians on the edge of the Great Dismal Swamp in Nansemond County.

The Nansemond, along with the

Chickahominy, Pamunkey, Mattapony, Rappahannock, and the Nanticoke of Delaware have for some years been organized as the revived Powhatan Confederacy of Indians.

West of the Nansemond in Southampton County between Sebrell and Courtland, there are asserted to be still remaining remnants of the Nottoway Tribe.

Piedmont and Blue Ridge Indian mixed-bloods.—Beginning with Rappahannock County in the north and continuing southward along the Blue Ridge through Rockbridge and Amherst Counties and striking directly southward to Halifax County on the North Carolina border we find small colonies of mixed people who claim Indian descent and are most generally called Issues.

Amherst County Issues.—This group of about 500 or 600 mixed-bloods is located in the central part of Amherst County about 4 or 5 miles west of the county seat. The principal settlements are on Bear Mountain and Tobacco Row Mountain in the Blue Ridge. At the extreme western end of the county is another mixed group of similar origin derived from Indian, white, and, in some localities, Negro blood. An Episcopal mission for the Issues is located 3 miles west of Sweet Briar College and comprises a school and other facilities.

The typical Issue is a very rich brunette with straight black hair and Caucasian features. The chief family names are Adcox, Branham, Johns, Redcross, and Willis. In the bottoms the Issues raise tobacco, while on the slopes corn and oats are cultivated. They are mostly renters and truck farmers. The white neighbors of these people are said to regard them as mulattoes. The term "Issue" is applied to mixed-bloods of the same type in many of the counties of Virginia.

Rockbridge County Brown People.—To the northwest of Amherst County in Rockbridge County is a small group located on Irish Creek, not more than 12 miles east of Lexington, Va., and called Brown People. Their number is estimated as over 300 and they show a mixture of white, Indian, and occasionally Negro blood. Like the Issues of Amherst County they are a group apart from both whites and Negroes.

Melungeons or Ramps.—In the counties located in the extreme western corner of Virginia are to be found scattered groups of mixed-bloods called Melungeons or Ramps. These people roam the mountain regions of Virginia, southern West Virginia, Tennessee, and Kentucky, and originally claimed Portuguese descent. The Virginia Melungeons are found on the mountain ridges such as Copper Ridge, Clinch Ridge, and Powell Valley in Lee and Scott Counties, in the vicinity of Coeburn and Norton in Wise County, near Damascus in Washington County, and in the western Dismal area of Giles County. No estimate of their numbers is available but they probably amount to several thousands. They show dark skins with straight or curly black hair and high cheek bones. Formerly they lived by raising a little corn, hunting, fishing, digging roots, gathering herbs, and doing odd jobs for their neighbors. In recent years they have taken to mining and cultivation in the better areas of bottom lands. The chief family names of Melungeons in this area are Bolen, Collins, Gibson or Gipson, Freeman, Goins, and Sexton.

Summary on Virginia Indians.—The remnants of Indian blood in Virginia can be divided into the Tidewater group and the Piedmont-Blue Ridge group. Both have lost the Indian languages and traditions almost entirely, but the former still maintains tribal organization and in some instances territorial reservations. The upland group shows no tribal organization but tends to retain traditions of Indian origin.

14. *North Carolina*

This State probably has the greatest number of pure-blood Indians of any

of the Atlantic-coast States between New York and Florida. The total number of Indians reported for North Carolina in 1930 was 16,579. Of these 37.9 percent were reported as full-bloods, 54.8 percent as mixed, and 7.3 percent were not recorded. The chief concentrations of Indian population were in the extreme western counties where the Cherokees are centered and in the southern border county of Robeson where the Croatans are centered. The policy of the State has been rather liberal in the matter of recognition and special provision for its Indian population. About 29.6 percent of these Indians 10 years of age or older were illiterate in 1930.

Cherokees.—The 1930 census reported 1,963 Cherokees in North Carolina. Unofficial estimates give a total of 3,700 Cherokees in this area. The census reported 38.7 percent pure-bloods in 1930, and 61.3 percent mixed. There is apparently very little Negro blood in this group. Most of the Cherokees are in Swain County where they have five "towns," Big Cove, Yellow Hill, Birdtown, Wolftown, and Painttown. Other groups are found in Graham and Cherokee Counties nearby and in Jackson County. The term "Qualla Reservation" denotes the five towns above mentioned plus certain other properties and covers about 55,784 acres. At Cherokee (Yellow Hill) the Federal Indian Office maintains an agency, a school, and certain medical facilities. Most of the Cherokees are small cultivators who raise a little corn in bottom lands and hillside patches. A few own a little livestock.

The Eastern Cherokee Band was incorporated under State law in 1889. The tribal government includes a chief elected every 4 years, and councilmen elected from each of the five towns and from the Graham County group. The Cherokee vote in some elections and pay State taxes. They still employ the native tongue and possess many of the magical practices, dances, games, and myths of their forefathers. Like their white neighbors they are Baptists and Methodists. In dress, diet, and houses they differ but little from the mountain whites.

Siouans or *Croatans.*—This group is estimated to number upwards of 16,000 persons and is thought to be increasing with greater rapidity than either whites or Negroes. Physical measurements indicate the presence of Indian, white, and Negro types. There is said to be a tendency for the lighter individuals and families to hold aloof from the darker ones just as in the case of the Nanticokes and the Narragansetts. They are found in greatest concentration in Robeson County but occur in considerable numbers in the nearby counties of Bladen, Columbus, Cumberland, Harnett, Sampson, and Scotland. Across the border in South Carolina they occur in Marlboro, Dillon, Marion, and Horry Counties.

The family names of these people are Allen, Bennett, Berry, Bridger, Brooks, Brown, Butler, Chapman, Chavis, Coleman, Cooper, Cumbo, Dare, Graham, Harris, Harvie, Howe, Johnson, Jones, Lasie, Little, Locklear, Lowrie, Lucas, Martin, Oxendine, Paine, Patterson, Powell, Sampson, Scott, Smith, Stevens, Taylor, Vicars, White, Willes, Wilkinson, Wood, and Wright. Their culture bears little of the Indian, but they claim partial descent from the "Lost Colony" of Raleigh at Roanoke.

Originally dwellers in the swamplands of the Lumbee River, they have become successful tenant farmers cultivating cotton, tobacco, and corn. The State has recognized their special status and they are endowed with a separate school system from both whites and Negroes. They have their own churches. Intermarriage with either Negroes or whites is forbidden by law and custom.

There are two factions today: one, calling itself the "Lumbee Indians," is located west and south of the Lumbee River; the other, calling itself "Cherokee," is located east and north

of the Lumbee River. The first group is poverty-stricken and lives under primitive conditions, while the second is more advanced, more numerous, and is economically as well off as its white neighbors.

Miscellaneous Indians of North Carolina.—In northeastern Person County on the Virginia border is located a group called Cubans who number about 400 persons. They also occur just across the State line in Halifax County, Va., around Christie and Virgilina. The chief family names are Coleman, Eps, Martin, Shepherd, Stewart, and Tally. The State of North Carolina maintains an Indian school for these people near High Plains. Near the school the Cubans maintain their own Baptist church. They also maintain their own social lodge. Marriage with either whites or Negroes is unusual on the part of these people.

These Person County Indians may be descendants of a small band of Saponi Indians who, according to early census reports, inhabited Granville County, N. C. (from which Person County was later set off).

In northeastern North Carolina in Dare and Hyde Counties and in Roanoke Island are to be found a few Indian remnants of the Machapunga Tribe mixed with white and Negro blood. Their family names are Pugh, Daniels, Berry, and Westcott. Just outside the town of Hertford, N. C., in Perquimans County there is a group of mixed-bloods who are called the Laster Tribe from their most common surname. They have a tradition of descent from a Moorish or Indian mixed-blood sea captain who long before the Civil War married a white woman and settled in this location. They maintain that they were never slaves and have held themselves somewhat aloof from the neighboring Negroes. At the present time they number several hundreds and many have gone westward to Indiana, Nebraska, and other States. In their original settlement they have their own school, church, and stores.

Somewhat to the west of Person County in Rockingham County the census of 1930 reports a considerable body of Indians. The identity of this group is not known. Likewise in Nash County, eastward of Raleigh, a small Indian group is recorded in the census of 1930. In Macon County near the Cherokee country some Croatans are said to have settled.

15. *South Carolina*

The 1930 census reports 969 Indians in South Carolina, primarily in Marlboro, Dillon, and York Counties along the northern borders, and in Sumter and Orangeburg Counties of the central part of the State. About 23 percent were reported as mixed-bloods, 26 percent as full-bloods, and the rest were not recorded. About 38 percent of the Indians were reported as illiterate. The census apparently reported only a small part of the population claiming Indian descent, and locally the mixed groups are often regarded as light mulattoes. There are some seven or eight groups distinguished by different names in the various counties of the Coastal Plain and Piedmont areas of the State. These are shown in the following table.

TABLE 1.—*Indian groups in South Carolina*

Group	*Counties where found*
1. Croatans	Marlboro, Dillon, Marion, Horry, along northeastern borders of the State.
2. Marlboro Blues	Chesterfield, on northern border of the State.
3. Catawba	York, on northern border of the State.
4. Brass Ankles	Charleston, Colleton, Dorchester, Berkeley, Orangeburg, and Clarendon, coastal and adjacent areas of the State.
5. Red Bones	Richland, around Columbia, the State capital.
6. Buckheads	Bamberg, southern part of the State.
7. Turks	Sumter, east of Columbia, the capital.
8. Red Legs	Orangeburg, north of Bamberg.

Four major geographical groups may be distinguished, namely, (1) Catawba, on northern border, (2) Croatans, also on northern border, (3) Red Legs and allied groups about the capital, and (4) Brass Ankles in coastal areas. Altogether these groups may total over 10,000 persons. In general they are similar to each other in manner of living and social status. They have lost almost everything that would distinguish them as Indians except the physical inheritance. The latter is of course greatly modified by mixture with white and Negro blood, yet these people are recognized locally as being distinct from both whites and Negroes. They have their own mixed-blood schools (locally classified as white), churches, and lodges.

The chief family names among these mixed bloods are Boone, Braveboy, Bunch, Chavis, Creek, Driggers, Goins, Harmon, Russell, Scott, Swett, and Williams. Formerly isolated by geographical factors they have, in recent years, been increasingly brought into contact with the world about them. They are hunters, fishers, and tenant farmers.

Catawbas.—The remnants of this tribe are located at a small settlement on the banks of the Catawba River in York County, about 9 miles southeast of Rockhill, the county seat. The settlement is about 1 square mile in area, or 630 acres. The 1930 census returned 159 Indians in York County. Their blood seems to be mostly a mixture of white and Indian.

Although they are directly under the laws of South Carolina they maintain a semblance of tribal government, electing a chief every 4 years. Conditions have long been unsatisfactory with respect to economic and social matters. The State has annually appropriated a sum of money to support the local school, but there are no local social agencies to assist the Catawbas. These Indians cut and haul wood and are employed as day laborers. The women often make clay pottery and pipes. Federal assistance has been given to these Indians in recent years.

16. *Georgia*

In most of the counties along the northern border of this State are to be found many hundreds of people of part-Cherokee descent, but these do not constitute a distinct social class. However, it is reliably reported that a small group of about 100 or more Cherokees and Creeks are at present located in a settlement near Shellbluff Landing in Burke County, about 10 miles south of Augusta and almost on the Savannah River. The family names are Clark, Woods, Shafer, and Deal. Their settlement is sometimes known as "Shaffertown" or "Shafferville" after the most common surname to be found there. A recent account carried by northern newspapers portrayed these Indians as living under rather primitive conditions, hunting, fishing, and cultivating in the manner of their early forefathers. In earlier days Yuchi, Shawnee, Apalachee, and Chickasaw Indians clustered in the vicinity of Augusta where the Savannah River crossed the fall line.

17. *Florida*

The census recorded 587 Indians in Florida in 1930, of which 53.3 percent were reported as pure-bloods, 0.4 percent as mixed, and 46.3 percent as not recorded. About 85 percent were reported as illiterate. The chief group is the Seminoles, whom we find scattered in half a dozen or more counties—Collier, Dade, Broward, St. Lucie, Glades, Hendry, Monroe, Okeechobee, and Osceola. This is the Everglades region from Lake Okeechobee southward, which constituted in the past century an ideal refuge for Indian hunters, living in a state of perpetual hostility to the white man.

The Seminoles speak their own language or languages and retain many of their aboriginal customs intact. They are largely self-governing and do not mix with other races. Legally they are entitled to send a

representative to the Florida State Legislature. The Federal Indian Office maintains an agency at Dania, just north of Miami, with a school for the Seminole.

Satisfactory knowledge about the Seminole is difficult to obtain owing to the wide dispersal of these Indians and the difficulty of access to the swamp country. Most of them have retreated to the inner recesses of the Big Cypress Swamp in the extreme south. When they emerge from the swamps they are treated as whites in most public places and facilities. In recent years, writers have become interested in the many survivals of Indian customs to be found among these people.

Aside from the Seminoles there are certain other small mixed groups of possibly Indian descent in Florida. Around Pensacola are to be found the Creole mixed people of Escambia County and in the same area are certain groups of Creeks from across the border in Alabama. Some 100 miles to the east near Blountstown in Calhoun County there is said to be a colony of Melungeons from Tennessee.

18. *Alabama*

According to the 1930 census there were 465 Indians in Alabama. Of these 1.7 were reported as full-blood, 74.4 percent as mixed-blood, and 23.9 percent were not recorded. About 36 percent of these 10 years of age or over were reported as illiterate. Persons of Indian blood are concentrated in certain counties, notably Mobile, Monroe, and Washington in the southwestern part of the State, where they are known as Creoles and Cajans; in Escambia and Covington Counties on the Florida border where they are known as Creeks; in Jackson County at the northeast corner of the State where they are Cherokees; and in Autauga County, just west of Montgomery, the State capital.

Creeks.—There are over 200 Indians of this tribe in Escambia County. An Episcopal mission has been maintained for these people at the town of Atmore, and there is also an Indian school. The title to the land on which these Indians live is in dispute. It was apparently sold some years ago to lumber companies for nonpayment of taxes, but the Indians have continued to live on it. Recent suits have been instituted in State courts to recover title for the Indians. The social status of these people is intermediate between that of Negroes and whites, and they are recognized locally as a distinct race.

Creoles.—The Creoles of Alabama are a mixed people who are possibly part Indian in blood. They are centered in Baldwin County and Mobile in small colonies numbering several hundred people. They are a separate social class intermediate in racial status between the whites and Negroes. They have their own schools and in Mobile their own fire department. Their family names are mainly French and they are all Roman Catholic in religion. Their occupations are farming, oyster shucking, and similar work. Some are found in the Pensacola area of Florida and others along the Mississippi coast. Educationally they have made considerable progress. Their chief family names are Allen, Andry, Belasco, Ballariel, Battiste, Bernoudy, Cassino, Cato, Chastang, Collins, Gomez, Hiner, Juzang, Lafargue, Laland, Laurendine, Laurent, Mazangue, Mifflin, Nicholas, Perez, Ponquinette, Pope, Reid, Taylor, and Trenier.

Cajans.—These people are centered in the area of heavy woods and hills about Citronelle in upper Mobile and lower Washington Counties, and number 3,000 or more. They are reputed to be part Indian and part white, while a certain number are also said to show Negro blood. Some show rather blond complexions while others are swarthy and black-haired. They live in small isolated communities which are very difficult of access. They subsist by lumbering and turpentine extraction, and are as a class rather poor. The

chief family names are Byrd, Carter, Chestang, Johnson, Jones, Rivers, Smith, Sullivan, Terry, and Weaver. Baptist and Methodist groups have missions among these people.

19. *Mississippi*

The 1930 census reported a total of 1,458 Indians in Mississippi, and of these, 11.2 percent were reported as pure-bloods, 75.1 percent as mixed, and 13.7 percent were not recorded. The figure for illiteracy of those 10 years old and over was 63.4 percent in 1930.

Choctaws.—The Mississippi Indians are almost all Choctaws and they are scattered through half a dozen counties in the central parts of the State. The greatest concentration is in Neshoba County around Philadelphia, but a large number are also found in Newton, Jasper, and Jones Counties to the south, in Leake and Scott Counties to the west, and in Kemper County to the east. The Federal Indian Office maintains an agency at Philadelphia, Miss., which includes a hospital and day school.

The native speech is employed among these people. Mission work has been carried on among them by the Methodist Episcopal and Roman Catholic groups. Cultivation of the soil and hunting, along with simple craftsmanship, help these Indians to make a living. They have been in bad straits economically and are looked down on by their white neighbors. It is said that these are the only Indians of the south who have been compelled as a class to use the Negro accommodations in railway travel.

20. *Louisiana*

The 1930 census reported 1,536 Indians in Louisiana, of which 11.2 percent were reported as full-bloods, 75.1 percent as mixed, and 13.7 percent as not recorded. Some 64.5 percent were recorded as illiterate. The principal groups are the Choctaw, Houma, and Chitimacha of the coastal areas, the Tunica of the lower Red River, the Red Bones of the southwest, and the Coushatta, a little to the southwest of the Tunica.

Houma.—These Indians, of very mixed blood, number upward of 1,000 and are increasing rapidly. They are located on Bayou Grand Caillou, south of the town of Houma, in Terrebonne and La Fourche Parishes. They are Roman Catholic, French speaking, dwell in palmetto huts and on houseboats; the men derive a living by fishing and trapping, and the women and children work in shrimp-canning factories nearby. The family names are Billiot, Verdin, Diane or Dean, Parfait, Gregoire, and Verret.

Chitimacha.—This group numbers some 240 members situated at various points in St. Mary's Parish, just west of Terrebonne. Some are settled around Charenton and although classed as Negroes refuse to attend colored schools. They number upward of 100 and are Roman Catholic in religion. They raise corn, sugarcane, and sweet potatoes. They speak both English and French. Marriage with Negroes is forbidden and some claim to be full-blood Indians. Two bands, numbering 150 persons in all, live at Verdonville, some 10 miles from Franklin, and are of mixed blood.

Tunica.—It is unofficially estimated that from 50 to 100 of this tribe, greatly mixed in blood, still live in Avoyelles, La Salle, Catahoula, and Rapides Parishes near the mouth of the Red River and the Yazoo. Near Marksville, La., there are 40 or 50 of these Indians living on a tract of 170 acres. Their property is not a reservation and they are not under any Federal supervision. They are not taxed, however. A few still speak the native language.

Coushatta or *Koasati.*—These people number about 250 and live in Allen Parish near Kinder, La. They own 1,050 acres of land. They claim to have no Negro blood and attend white public schools. There is a Congrega-

tional Mission among them. This group has resided in the locality since about 1800, when it migrated from Alabama.

Miscellaneous Louisiana Indians.—The Choctaw of Bayou Lacomb on the north shore of Lake Pontchartrain (St. Tammany Parish) formerly numbered some 50 persons. Small groups of Indian blood are also said to exist in Orleans (New Orleans) and Jefferson Parishes. The "Cane River Mulattoes" located on Cane River in Natchitoches Parish in the northwestern part of Louisiana may be of part-Indian descent as may be also the so-called mulattoes of Washington in St. Landry Parish, to the south of the Tunica country. Finally there are the mixed Indians of Calcasieu Parish on the Texas border, sometimes referred to as "Sabines," who were prominent in the border troubles of early days. Any of the mixed-blood Indians of this part of Louisiana may be referred to as "Red Bones," but this use of the term is not to be confused with the mixed people of the same name in South Carolina. The Red Bones probably number over 3,000 persons scattered about through the cut-over pine country of Calcasieu, Vernon, Allen, Rapides, and Beauregard Parishes. They have lived in this country for well over a hundred years, and a century ago they were classed as persons of color. Their family names are English (Ashworth, Perkins, etc.), and they are mostly Baptists. The occupations followed are small-scale farming, forest industries, or work in towns. Although they are now officially "white" and not segregated in schools, the whites proper do not intermarry with them. Members of this group are said to resent intensely the name "Red Bone."

In general, the Indians of Louisiana, like those of Alabama, have lost most of their Indian culture and Indian speech. In contrast with the Choctaws of Mississippi they are much more adapted to the white man's way of life.

21. *Texas*

The 1930 census reported 1,000 Indians in Texas. Of these 29.2 percent were reported as pure-blood, 26.2 percent as mixed-blood, and 44.6 percent were not recorded. About 18 percent of those 10 years of age and over were illiterate.

In some of the counties around Houston there were small groups of Indians, according to the census (Fort Bend and Harris Counties). A number are also recorded for Bexar County (San Antonio) and one or two other points.

Alabama and Coushatta Indians.—This group of over 300 Indians resides in Polk County some 80 miles northward of Houston, Tex. They are concentrated on an area of 14,321 acres near Livingston on Big Sandy Creek. They have lived here since 1854 when a grant was made by the State of Texas. They are farmers but still maintain many of the Indian customs, ornaments, and dances. The native speech is also retained. The State maintains an agent here, and there is a federally supervised school. There are two Presbyterian churches, a hospital, and a cemetery. These Indians elect a tribal chief and maintain the old clan system.

22. *Arkansas*

Some 408 Indians were recorded for this State in 1930 by the census. Of these 5.6 percent were reported as full-blood, 54.9 percent as mixed, and 39.5 percent were not recorded. The Indians in Arkansas are chiefly in counties along the border of Oklahoma (Benton, Sebastian, and Washing), in the State capital (Pulaski County), and in Garland County (Hot Springs).

23. *Missouri*

The census of 1930 reported 578 Indians in Missouri in 1930. Of these, 6.7 percent were reported as full-blood, 35.5 as mixed, and 57.8 as not

recorded. Most of these were in the counties bordering or nearest to Oklahoma (Newton, Jasper), and the counties of Jackson (Kansas City), and St. Louis (city of St. Louis).

24. *Tennessee*

The Indians of Tennessee numbered 161 in 1930. Of these, 0.6 percent were full-blood, 26.1 percent mixed-blood, and 73.3 percent not recorded. These were probably either mixed-blood people such as the Melungeons, or the purer-blooded Cherokees. The Cherokees are very few and are probably located exclusively in the eastern mountain counties. The census figure is thought to be an understatement.

Melungeons.—This interesting minority comprises several thousand persons who were originally centered in Hawkins County (now Hancock County) on Newman's Ridge in the extreme northeast of the State. They have also been reported from various other counties in the Appalachian Great Valley area, especially Rhea and Hamilton Counties, and also in the Nashville area. The chief family names in Tennessee are Collins, Fields, Freeman, Gann, Gibson, Goins, Gorvens, Graham, Lawson, Maloney, Mullins or Melons, Noel, Piniore, Sexton, and Wright.

Originally ridge cultivators, they have had to resort to additional means of living in recent times, including basketmaking, cooperage, chairmaking, and charcoal burning. Their manner of life is emphatically out-of-doors in character. Their physical type shows the usual range of mixed-blood between lighter and darker types. Indian, white, and especially Portuguese blood are said to be prominent.

Socially they have been recognized as white in the courts and now attend white schools. Illiteracy is widespread however. They have no separate organizations except churches, and they are gradually merging with the remainder of the population.

25. *Kentucky*

Some 234 Indians were recorded for Kentucky in 1910. Later census figures do not enumerate as many. Most of the Indians enumerated were in Magoffin and Floyd Counties in the eastern part of the State.

In southern Kentucky on the Tennessee border (in Cumberland and Monroe Counties) is the Coe Clan, a mixed group of part-Indian descent. These people live on Pea Ridge along the Cumberland River in an area bounded partly by that river on the south and west, by Kettle Creek on the east, and Gudio Creek on the north.

26. *Ohio*

There were 435 Indians in Ohio in 1930, 6 percent pure-blood, 20.9 percent mixed, and 73.1 percent not recorded, according to the census. These returns show their presence mainly in the cities of the State, as in Cleveland (Cuyahoga County), Columbus (Franklin County), Cincinnati (Hamilton County), Toledo (Lucas County), and Akron (Summit County). There were also a few Indians in rural Hardin County who may represent a survival from early times (a few refugees), in the Scioto marshes, and the settlement at Carmel.

There are a number of mixed-blood groups of part-Indian descent in Ohio who are not recorded in the census. The most notable of those is the Darke County mixed-blood group located near Tampico on the Indiana border about 40 miles northeast of Dayton, Ohio. This settlement dates back to the early nineteenth century, and members of the group still hold themselves apart from both Negroes and whites. At present they are said to number about 60 families, and they have their own schools and churches (Methodist).

Near the village of Carmel, Ohio, about 65 miles east of Cincinnati, there is a small group of mixed-blood

Indians. They dated back to 1858, when a white man moved here from Virginia with a dozen Negro retainers about the time of the Civil War. The latter mixed with other people who had arrived not long before from Magoffin County in eastern Kentucky and who were reputedly of Indian descent. The present-day Carmel Indians live in shacks on the farmers' lands, where they provide occasional labor and subsist by hunting, sale of ginseng and yellow root, and by their scant stock of chickens and pigs. A few own small plots but the rest have been said to be on relief recently. Many migrated from the area during World War II, but about 50 still remain in the neighborhood. The family names are Nichols, Gibson, and Perkins.

27. *Indiana*

Although the census of 1930 enumerates only 285 Indians in Indiana in 1930 the number of Miami Indians in the State have been variously estimated in recent years as from 500 to 1,000. These Indians chiefly center in Miami County, 50 or 60 miles directly north of Indianapolis, but they also occur in some numbers in Wabash County east of Miami, and in Marion County (Indianapolis). Several congressional hearings have been held in recent years on the matter of land claims by these Indiana Indians. The 1930 census returns 7 percent as pure-blood, 28.8 percent as mixed-blood, and 64.2 percent as not recorded.

28. *Illinois*

The 1930 census reported 469 Indians in Illinois. These were chiefly in Cook County (Chicago), Alexander County (Cairo), and in Peoria County (Peoria). No data are available on the condition of these Indians. The proportions of mixed- and pure-bloods reported in 1930 are about the same as those for Indiana.

There are also reported to be a number of Creek Indians from the south along the route of the Illinois Central Railroad. In southern Illinois, not far from Centralia, a mixed-blood group of such Indians is said to exist.

Condition in General

The names by which the groups of surviving Indians in the eastern United States are known are of several origins. In the first place we have the survival of older tribal names such as Seneca, Cherokee, Nanticoke, and so on. In several instances it seems that the old tribal name was practically forgotten until anthropological investigators reinstilled an interest in the original name. About one-half of the surviving eastern groups of Indians are still known by historic tribal designations. The remainder of the groups are known by names derived from places, color terms, nationality or race terms, family names, ancestors, or from traditional origins or manner of living.

Places figure prominently in several instances. In South Carolina we hear of the Summerville Indians, in Louisiana of the Sabines (from the Sabine River), and in West Virginia of the G. and B. Indians (after the Grafton and Belington Railroad). The Guineas of West Virginia are supposed to derive their name from the district called Guinea on the Tygart River. Reservation or place names, with the word "Indian" attached, may serve as handy designations as in "Carmel Indians" (Indians of Carmel, Ohio) or "Cornplanter Indians" (Indians of Cornplanter Reservation, Pa.).

The use of color terms is rather infrequent except where mulatto blood is suspected. In Virginia we hear of the "Brown People" in Rockbridge County; in Chesterfield County, S. C., of the Marlboro Blues; and in several places of Red Bones and Yellow People. The term "Brass Ankle" is thought by some to refer to a toasted brown color (Spanish abrasado).

Nationality or race terms are more frequent than color terms, and we hear

of "Greeks," "Turks," and "Cubans," in the Carolinas, of "Moors" in Delaware and New Jersey, and "Arabs" in New York. More confusing still is the use of the term "Cajan" to refer to a mixed-blood group in Alabama. Brewton Berry has proposed that the term "Mestizo" be adopted from Spanish-American terminology in referring to all mixed-blood groups with an Indian element.

Family names characteristic of small groups of mixed-blood descent may be used to designate the groups themselves. Thus we have the Laster Tribe, the Coe Clan, the Pools, the Slaughters, the Van Guilders, the Goins, and the Maleys. The last term mentioned is used for the Guineas of West Virginia owing to the frequency of that surname. Of a similar sort are the names from ancestors such as the Cornplanter Seneca.

The traditional origin or the current manner of life is prominent in such names as Croatans, Issues, Jackson Whites, Wesorts, Bushwhackers, Pondshiners, Pineys, Melungeons, and Clay-eaters. In some instances writers have used pseudonyms for groups such as the Win Tribe (Issues of Amherst County, Va.), the Nams, Jukes, and others.

Mixed-blood groups which have lost most of the Indian cultural heritage yet continue a caste-like habit of inbreeding, are characterized by certain fixed sets of family names. Most of the groups average anywhere from 10 to 14 characteristic family names. Curiously enough a number of these families are found in more than one group and this would point to a possibility of some degree of intermarriage between them at various times in the past. The Croatans, for example, share names with the Cubans, Issues, Melungeons, Brass Ankles, Cajans, and Nanticokes. Not only do such nearby groups as the Nanticokes and Moors share names but we find such sharing by groups rather remote from each other, as for example, the Cajans and Moors, Brass Ankles and Nanticokes, or Melungeons and Brass Ankles. On the other hand, the Jackson Whites and the New England mixed groups show little if any evidence of sharing family names with the other groups.

The size of most of the eastern groups of Indian mixed peoples is not accurately known. Since membership in these groups may be somewhat elastic, estimates are bound to be rather arbitrary. In general it may be said that the number of specific groups range from a hundred individuals up to several thousands. In fact this compares very well with the western tribes of Indians as may be seen from the fact that in 1930 the average Indian tribe ranged between 1,000 and 2,500 in size. Out of 90 western tribes 43 were less than 700 in number, 40 were between 700 and 7,000, and 7 were from 7,000 to 45,000. The Croatans may be compared with the Navajos, in terms of numbers and relative size to the rest of their neighbors. Both are the largest groups of their respective areas.

In contrast with the western Indians the eastern groups do not have any major settlements of their own. Almost all the concentrations of eastern Indians are in close connection with white or Negro centers of population. In many instances the Indian populations are widely scattered in remote and inaccessible areas in both East and West. In tracing the location of the eastern Indians it is often necessary to relate their populations to minor civil divisions of the county such as townships and election districts. The eastern Indians are well on the way to becoming a caste rather than localized territorial groups, and hence their distribution follows that of the population in general. Migratory habits are confined to the necessity of seeking economic subsistence in cities or manufacturing areas.

The more isolated and primitive mode of life is pursued by certain

groups who do hunting, fishing, lumbering, turpentine extraction, and collecting of herbs and roots. Basketry and beadwork still survive among these groups. Others more advanced are cultivators, truck and dairy farmers. Still other groups have gone farther along the road to adjustment to modern civilization. This group is composed of migrants to cities or industrial areas who labor as miners, domestic servants, oyster shuckers, cigar makers, cotton samplers, artisans, petty tradesmen, junkmen, repairmen, cannery workers, iron and steel workers, and the like.

The history of the eastern Indians subsequent to the Colonial Period is to a great extent unknown. It was not until the latter part of the nineteenth century that an interest in the mixed-blood Indian groups began to reawaken; especially with the first census of the United States Indian population in 1890. The group known as the Croatans, for example, were known as far back as the Civil War period, but it was only when the investigations of Hamilton Macmillan about 1885 led to the formulation of the "Lost Colony" theory that the groups became generally known. About the same time (1889 and 1891) Swan M. Burnett and Miss Dromgoole called attention to the hitherto unnoticed Melungeons in eastern Tennessee, and Babcock described the Nanticoke Indians of Indian River, Delaware (1889).

In 1889, also, James Mooney, anthropologist of the Smithsonian Institution, sent out a set of questions on Indian survivals to local physicians in certain counties of Maryland, Virginia, Delaware, and North Carolina. One of the questions read as follows: "Please give the names and addresses of any individuals of pure or mixed Indian blood in your vicinity, and state to what tribes they belong. If any considerable number live in one settlement please give the names of one or two who may be able to afford information." The replies to this circular letter may still be seen in the archives of the Bureau of American Ethnology. From these documents it is apparent that a great number of local groups of Indian extraction were in existence at that time in the four States mentioned. Although no publication resulted from this study it is quite evident that both Mooney and William H. Holmes, the latter then Chief of the Bureau of American Ethnology, continued an interest in the eastern Indian survivals because we have the report that in 1912 Mooney, in addition to his work with the eastern Cherokees, made a trip to southern Maryland to investigate the Wesorts.

It was shortly after the first Indian census that George P. Fisher, in 1895, published the first account of the Moors of Delaware, close neighbors of the Nanticoke who had been first noticed a few years previously.

The date of the second major census of Indians in 1910 was marked by the discovery of still more mixed-blood groups of Indian descent in the East. These groups were: (1) the Jackson Whites (described by Frank Speck in 1911); (2) the Issues of Amherst County, Va. (described by Rev. A. P. Gray in 1908); and (3) the Wesorts (existence first noted under that name by Mooney in 1912, as has been indicated above). In 1912 Paul Converse published his excellent report on the Melungeons, adding numerous data to the material first collected by Dromgoole.

The third major census of Indians in 1930 was the occasion for the "discovery" of two more Indian mixed groups, (1) the Brass Ankles of South Carolina and their relatives of the same State (later studied in detail by Brewton Berry in 1944), and (2) the Cajans and Creoles of Alabama, described in the same year by Horace Bond and Carl Carmer (1931). If a major study of Indians is made a part of the coming census of 1950 it

may be expected that still more groups of this sort will appear in the literature.

Some of the mixed-blood Indian groups have attracted the attention of fiction writers. In Shelby and Stoney's "Po' Buckra" (1930), the central figure is a Brass Ankle who attempts to adapt himself to the life of a southern (white) planter but in the end finally returns to the hunting and fishing life, the carefree existence of his forefathers. In their romantic novel, "The King of Scuffletoun" (1940), Lucas and Groome tell a melodramatic story woven about the life and adventures of the famous Croatan outlaw of Civil War times, James Lowrie. Albert Payson Terhune, in a boy's book entitled "Treasure" (1926), describes the Jackson Whites with considerable vividness.

A somewhat different approach to mixed-blood Indians is taken by James Aswell and E. E. Miller in their series of fantastic tales about Tennessee Melungeons, which form a section of the volume entitled "God Bless the Devil" (1940). In this work the local dialect is used with remarkable effect to tell about the Melungeons the impossible and exaggerated occurrences so frequently recounted at country courthouses by local storytellers. In a somewhat similar vein but of far more serious intent is Mildred Haun's "The Hawk's Done Gone" (1940), a series of local dialect biographies of the whites and Melunggeons of a section in eastern Tennessee. Roy Flannagan, in his novel, "Amber Satyr" (1932), describes the recent struggle for Indian status on the part of members of the mixed-blood groups in coastal Virginia, while Lyle Saxon's "Children of Strangers" (1937) portrays a similar situation in Louisiana.

Aside from the literary notices of these mixed Indian groups there are evidences of a considerably longer historical background than one might at first expect. In most of the Atlantic-coast groups (Brass Ankles, Croatans, Wesorts, Moors, and Nanticokes) for example, it is evident from the early censuses that as far back as 1790 the ancestors of these groups were living in the same locations as we find them today and were classified as mixed-bloods then also. The family names of the groups in 1790 were practically the same as they are today. How much earlier than 1790 these families were in the same locality has not been ascertained.

For the groups farther away from the east coast, Melungeons, Guineas, Cajans, and Jackson Whites, the family names appear in the census records at various times from 1830 through 1870. The census records can therefore be used to demonstrate a rather early appearance of the mixed-blood Indian communities in the eastern States in most cases long before any literary notice of these groups.

The names or nicknames, however, by which these groups are known today may be of comparatively recent origin. The term "Croatan" came into use about 1885 owing to the promulgation of the theory that this group was descended from Sir Walter Raleigh's lost colonists on Roanoke Island. The name "Wesort" first appeared in local parish records about 1896.

At the present time the Indian mixed groups of the eastern States are in a process of transition. Up until about 20 years ago, for example, the Brass Ankles of South Carolina lived in the isolation of river swamps and pine barrens, in small clearly marked-off racial "islands." Since then improvement in the means of communication and programs of the W. P. A. and F. S. A. during the thirties have broken down this isolation. The members of mixed-blood communities are now tending to disperse and many of these groups have decreased in size, a few almost becoming extinct. This process results in two sections, (1) a group of

stay-at-homes, frequently the conservative, more Indian-like and older people; and (2) the migrants, often younger persons, who settle in cities or industrial areas. The members of the first section continue to exist as a caste apart with their own racial schools, and often their own churches, clubs, and stores. They continue to confuse the selective service on racial classification although many go as white, and they continue to have a rather high birth rate. This latter feature casts doubt on the prediction that these groups will soon disappear. The migrants, on the other hand, who go to northern and western cities are absorbed partly by the white and partly by the colored communities.

The fertility of these Indian mixed groups is a matter worthy of some emphasis. In this respect the Indian mixed-bloods of the United States resemble the Caboclos (mainly Indian-white crosses) of Brazil who show a relatively greater reproduction rate than other elements of the population. According to a study by Roland M. Harper, the Croatan birth rate in 1933 was 35.4 per thousand as compared with 22.3 for the whites and 24.5 for the Negroes. Similar rapid rates of increase are to be found, to all appearances, among the Houma, Wesorts, Guineas, and other such groups. This increase, if continued, means that the Indian mixed-blood groups will play an important part in the future population make-up of their respective States and may also influence future State politics.

Certain hereditary physical peculiarities are exhibited occasionally by the inbred eastern Indian mixed-bloods. The occurrence of albinos has been noticed among the Wesorts and the Jackson Whites. A similar occurrence of albinism was noted by Hrdlička for the inbred Hopi and Zuñi of the Southwest. Among the Wesorts, cases of microdontism or short teeth run in certain families, while among the Nanticoke Weslager reports a thickened condition of the upper eyelid which results in droopy eyes (ptosis) in some families. Hereditary deformities in the joints are reported as occurring among the West Virginia Guineas. Hereditary diseases of the nervous system such as congenital deafness and blindness, and speech defects are reported among the Wesorts.

Some writers have associated dysgenic qualities generally with certain of the mixed-blood Indian groups of the eastern States. Whether these alleged traits are due to inbreeding or not is difficult to establish. Many of these mixed-bloods have lived under social conditions that are not calculated to bring out their more admirable traits. The South Carolina mixed-bloods are spoken of as hypersensitive, shy, furtive, self-conscious, hypercritical, and obviously suffering from an inferiority complex.

Where it is strongly established, the attitude of negativism on the part of Indian mixed-bloods is shared by the neighboring whites with the result that the whole subject of race relations is taboo. Any attempt by outsiders to investigate the situation often meets with silence or even violent response. Brewton Berry notes that mixed-bloods in South Carolina are virtually never the subject of conversation in white society and are not mentioned in newspapers and histories. These outcastes have no written history, no family genealogies reposing in State historical archives, no part in the social register, and so on. In this respect they resemble preliterate societies and offer a fertile field for anthropological research.

The Indians of the eastern States represent today the results of the solution of the Indian problem by the individual States with a minimum of Federal interference. With the partial exception of the various Iro-

quoian groups in New York, and in recent years the eastern Cherokee, eastern Seminole, eastern Choctaw, and perhaps one or two others, the eastern Indians have not in general had any direct assistance or guidance from Federal sources. In a few instances State reservations, as in Maine, Connecticut, and Virginia, have furnished a small amount of security to small Indian remnants. But in the main the results are all too obvious. These unassisted Indian groups have in general sunk to a rather low level of society indeed and have come to form, so to speak, a sort of vaguely marked caste separate from both whites and Negroes. All in all they appear to have lost in becoming "civilized" far more than they have gained. And, most portentiously of all, does this not point out the possible future fate of the present-day Indians of the western States as well?

APPENDIX I. INDIAN SURVIVALS, EASTERN STATES

1. MAINE:
   - Penobscot.
   - Passamaquoddy.
   - Malecite.
2. VERMONT.
   - None described.
3. NEW HAMPSHIRE:
   - Pennacook.
4. MASSACHUSETTS:
   - Wampanoag.
   - Nipmuc.
5. RHODE ISLAND:
   - Narragansett.
6. CONNECTICUT:
   - Pequot.
   - Mohegan.
   - Schaghticoke.
   - Paugusett.
   - Niantic.
7. NEW YORK:
   - Cattaraugus Seneca.
   - Allegany Seneca.
   - Tuscarora.
   - Tonawanda Seneca.
   - Onondaga.
   - St. Regis Mohawk.
   - Oneida.
   - Shinnecock.
   - Poosepatuck.
   - Montauk.
   - Matinecock.
   - Setauket.
   - Bushwhackers.
   - Pondshiners.
   - Van Guilders.
   - Slaughters, Honies, Clappers, Arabs.
   - Jackson Whites.
   - New York City groups.
8. NEW JERSEY:
   - Jackson Whites.
   - Pineys.
   - Sand Hill Indians.
   - Moors.
9. PENNSYLVANIA:
   - Cornplanter Seneca.
   - Pools.
   - Philadelphia groups.
   - Cherokee (Cumberland Valley).
10. DELAWARE:
    - Moors.
    - Nanticoke.
11. MARYLAND:
    - Wesorts.
12. WEST VIRGINIA:
    - Guineas.
13. VIRGINIA:
    - Chickahominy.
    - Pamunkey.
    - Mattapony.
    - Rappahannock.
    - Potomac.
    - Wicomico.
    - Accohannock.
    - Werowocomoco.
    - Nansemond.
    - Nottoway.
    - Powhattan.
    - Issues.
    - Brown People.
    - Melungeons.
14. NORTH CAROLINA:
    - Cherokee.
    - Croatans.
    - Cubans.
    - Rockingham County.
    - Nash County.
    - Machapunga.
    - Laster Tribe.
15. SOUTH CAROLINA:
    - Croatans.
    - Brass Ankles.
    - Red Bones.
    - Buckheads.
    - Turks.
    - Red Legs.
16. FLORIDA:
    - Seminole.
    - Creole.
17. ALABAMA:
    - Creek.
    - Creole.
    - Cajans.
18. MISSISSIPPI:
    - Choctaw.
19. LOUISIANA:
    - Houma.
    - Chitimacha.
    - Tunica.
    - Coushatta.
    - Choctaw.
    - Red Bones.
20. TEXAS:
    - Alabama and Coushatta.
21. ARKANSAS:
    - None described.
22. TENNESSEE:
    - Melungeons.
23. KENTUCKY:
    - Coe Clan.
    - Magoffin County.
24. OHIO:
    - Darke County.
    - Carmel Indians.
    - Guineas.
25. INDIANA:
    - Miami.
26. ILLINOIS:
    - None described.

APPENDIX II. COUNTIES OF THE EASTERN STATES IN WHICH INDIAN GROUPS OCCUR

1. Maine:
   - Aroostook.
   - Penobscot.
   - Washington.
2. Massachusetts:
   - Barnstable.
   - Bristol.
   - Dukes.
   - Norfolk.
   - Plymouth.
   - Suffolk.
   - Worcester.
3. Rhode Island:
   - Newport.
   - Providence.
   - Washington.
4. Connecticut:
   - Fairfield.
   - New London.
5. New York:
   - Cattaraugus.
   - Chautauqua.
   - Columbia.
   - Erie.
   - Franklin.
   - Genesee.
   - Jefferson.
   - Kings (Brooklyn).
   - Madison.
   - Monroe.
   - Niagara.
   - Onondaga.
   - Orange.
   - Rensselaer.
   - Rockland.
   - St. Lawrence.
   - Schoharie.
   - Suffolk.
6. New Jersey:
   - Bergen.
   - Morris.
   - Monmouth.
   - Passaic.
7. Pennsylvania:
   - Alleghany (Pittsburgh).
   - Bradford.
   - Bucks.
   - Cumberland.
   - Philadelphia.
   - Warren.
8. Delaware:
   - Kent.
   - Sussex.
9. Maryland:
   - Charles.
   - Prince Georges.
   - Talbot.
10. West Virginia:
    - Barbour.
    - Taylor.
11. Virginia:
    - Accomac.
    - Amherst.
    - Caroline.
    - Charles City.
    - Chesterfield.
    - Elizabeth City.
    - Essex.
    - Giles.
    - Gloucester.
    - Halifax.
    - Hanover.
    - Henrico.
    - King and Queen.
    - King William.
    - Lee.
    - Nansemond.
    - New Kent.
    - Norfolk.
    - Northampton.
    - Northumberland.
    - Rockbridge.
    - Russell.
    - Scott.
    - Southampton.
    - Suffolk.
    - Washington.
    - Wise.
12. North Carolina:
    - Bladen.
    - Cherokee.
    - Columbus.
    - Cumberland.
    - Graham.
    - Harnett.
    - Hertford.
    - Hoke.
    - Hyde.
    - Jackson.
    - Macon.
    - Marion.
    - Nash.
    - Perquiman.
    - Person.
    - Richmond.
    - Robeson.
    - Rockingham.
    - Sampson.
    - Scotland.
    - Swain.
13. South Carolina:
    - Bamberg.
    - Berkeley.
    - Charleston.
    - Chesterfield.
    - Colleton.
    - Dillon.
    - Dorchester.
    - Horry.
    - Marlboro.

13. South Carolina—Con.
    - Marion.
    - Orangeburg.
    - Richland.
    - Sumter.
    - York.
14. Georgia:
    - Evans.
15. Florida:
    - Broward.
    - Collier.
    - Dade.
    - Escambia.
    - Glades.
    - Hendry.
    - Lee.
    - Martin.
    - Okeechobee.
    - Monroe.
    - Osceola.
    - St. Lucie.
16. Alabama:
    - Autauga.
    - Baldwin.
    - Clarke.
    - Covington.
    - Escambia.
    - Jackson.
    - Mobile.
    - Monroe.
    - Washington.
17. Mississippi:
    - Greene.
    - Jasper.
    - Jones.
    - Kemper.
    - Leake.
    - Neshoba.
    - Newton.
    - Perry.
    - Scott.
18. Louisiana:
    - Allen.
    - Avoyelles.
    - Calcasieu.
    - Catahoula.
    - Jefferson.
    - La Fourche.
    - La Salle.
    - Orleans.
    - Rapides.
    - St. Landry.
    - St. Mary.
    - St. Tammany.
    - Terrebonne.
    - Vernon.
19. Texas:
    - Bexar.
    - Ft. Bend.

APPENDIX II. COUNTIES OF THE EASTERN STATES IN WHICH INDIAN GROUPS OCCUR—Continued

19. Texas—Continued
    - Harris.
    - Polk.

20. Arkansas:
    - Benton.
    - Garland.
    - Pulaski.
    - Sebastian.
    - Washington.

21. Missouri:
    - Jackson.
    - Jasper.
    - St. Louis City.

22. Tennessee:
    - Campbell.
    - Cannon.
    - Hancock.
    - Hawkins.
    - Shelby.

23. Kentucky:
    - Cumberland.
    - Floyd.
    - Magoffin.
    - Monroe.

24. Ohio:
    - Cuyahoga.
    - Darke.

24. Ohio—Continued
    - Franklin.
    - Hamilton.
    - Hardin.
    - Highland.
    - Lucas.
    - Summit.

25. Indiana:
    - Marion.
    - Miami.

26. Illinois:
    - Alexander.
    - Cook.
    - Peoria.

APPENDIX III. FAMILY NAMES OF EASTERN INDIAN GROUPS

1. Accohannock (Virginia):
    - Miles.
2. Brass Ankles, etc. (South Carolina):
    - Boone.
    - Braveboy.
    - Bunch.
    - Chavis.
    - Criel.
    - Driggers.
    - Goins.
    - Harmon.
    - Russell.
    - Sammons.
    - Scott.
    - Shavis.
    - Swett.
    - Williams.
3. Bushwhackers (New York):
    - Hotaling.
    - Proper.
    - Simmons.
4. Cajans (Alabama):
    - Byrd.
    - Carter.
    - Chastang.
    - Johnson.
    - Jones.
    - Rivers.
    - Smith.
    - Sullivan.
    - Terry.
    - Weaver.
5. Carmel Indians (Ohio):
    - Gibson.
    - Nichols.
    - Perkins.
6. Chickahominy (Virginia):
    - Adkins.
    - Bradby.
    - Coleman.
    - Holmes.
    - Jefferson.
    - Jones.
    - Miles.
    - Stuart.
    - Swett.

6. Chickahominy (Virginia)—Continued
    - Thompson.
    - Wynne.
7. Creoles (Alabama):
    - Allen.
    - Andry.
    - Belasco.
    - Ballariel.
    - Battiste.
    - Bernoudy.
    - Cassino.
    - Cato.
    - Chastang.
    - Collins.
    - Gomez.
    - Hiner.
    - Juzang.
    - Lafargue.
    - Laland.
    - Laurendine.
    - Laurent.
    - Mazangue.
    - Mifflin.
    - Nicholas.
    - Perez.
    - Ponquinette.
    - Pope.
    - Reid.
    - Taylor.
    - Trenier.
8. Croatans (North Carolina):
    - Allen.
    - Bennett.
    - Berry.
    - Bridger.
    - Brooks.
    - Brown.
    - Butler.
    - Chapman.
    - Chavis.
    - Coleman.
    - Cooper.
    - Cumbo.
    - Dare.
    - Graham.
    - Harris.

8. Croatans (North Carolina)—Continued
    - Harvie.
    - Howe.
    - Johnson.
    - Jones.
    - Lasie.
    - Little.
    - Locklear.
    - Lowry.
    - Lucas.
    - Martin.
    - Oxendine.
    - Paine.
    - Patterson.
    - Powell.
    - Revels.
    - Sampson.
    - Scott.
    - Smith.
    - Stevens.
    - Taylor.
    - Viccars.
    - White.
    - Willis.
    - Williamson.
    - Wood.
    - Wright.
9. Cubans (North Carolina and Virginia):
    - Coleman.
    - Epps.
    - Martin.
    - Shepherd.
    - Stewart.
    - Tally.
10. Hassanamisco Nipmuc (Massachusetts):
    - Barber.
    - Belden.
    - Brown.
    - Cisco (Sisco).
    - Curliss.
    - Gidger or Gigger.
    - Gimbey.
    - Hamilton.
    - Hector.
    - Hemingway.

APPENDIX III. FAMILY NAMES OF EASTERN INDIAN GROUPS—Continued

10. Hassanamisco Nipmuc (Massachusetts)—Continued
    - Lewis.
    - Moore.
    - Peter.
    - Scott.
    - Tony.
    - Williams.
11. Guineas (West Virginia):
    - Adams.
    - Collins.
    - Croston.
    - Dalton (Dorton).
    - Kennedy.
    - Male or Mayle.
    - Miner or Minear.
    - Newman.
    - Norris.
    - Pritchard.
12. Issues (Virginia):
    - Adcox.
    - Branham.
    - Johns.
    - Redcross.
    - Willis.
13. Jackson Whites (New York and New Jersey):
    - Casalony.
    - Cisco.
    - De Vries.
    - De Groat.
    - Mann.
    - Van Dunk.
14. Machapunga (North Carolina):
    - Berry.
    - Daniels.
    - Pugh.
    - Westcott.
15. Mattapony (Virginia) Lower Group:
    - Allmond.
    - Collins.
    - Costello.
    - Langston.
    - Major.
    - Reid.
    - Tuppin.
16. Mattapony (Virginia) Upper Group:
    - Adams.
    - Holmes.
17. Melungeons (Virginia and Tennessee):
    - Bolen.
    - Collins.
    - Denham.
    - Fields.
    - Freeman.
    - Gann.
    - Gibson.
    - Goins.
    - Gorvens.
    - Graham.

17. Melungeons (Virginia and Tennessee)—Continued
    - Lawson.
    - Maloney.
    - Mullins.
    - Noel.
    - Piniore.
    - Sexton.
    - Wright.
18. Moors (Delaware):
    - Carney.
    - Carter.
    - Carver.
    - Coker.
    - Dean.
    - Durham.
    - Hansley.
    - Hansor.
    - Hughes.
    - Morgan.
    - Moseley.
    - Munce.
    - Reed.
    - Ridgeway.
    - Sammons.
    - Seeney.
19. Nansemond (Virginia):
    - Boss.
    - Weaver.
20. Nanticoke (Delaware):
    - Bumberry.
    - Burke.
    - Burton.
    - Clarke.
    - Cormeans.
    - Coursey.
    - Davis.
    - Drain.
    - Hansor.
    - Harmon.
    - Hill.
    - Jackson.
    - Johnson.
    - Kimmey.
    - Layton.
    - Miller.
    - Morris.
    - Moseley.
    - Newton.
    - Norwood.
    - Reed.
    - Ridgeway.
    - Rogers.
    - Sockum.
    - Street.
    - Thomas.
    - Thompson.
    - Walker.
    - Wright.
21. Pamunkey (Virginia):
    - Bradby.
    - Collins.
    - Cook.
    - Dennis.
    - Hawkes.
    - Holmes.

21. Pamunkey (Virginia)—Continued
    - Langston.
    - Miles.
    - Page.
    - Sampson.
    - Swett.
22. Pools (Pennsylvania):
    - Heeman.
    - Johnson.
    - Van der Pool.
    - Vincent.
    - Wheeler.
23. Rappahannock (Virginia):
    - Nelson.
24. Red Bones (Louisiana):
    - Ashworth.
    - Bedgood.
    - Butters.
    - Buxton.
    - Clark.
    - Cloud.
    - Doyle.
    - Dyess.
    - Hyatt.
    - James.
    - Johnson.
    - Maddox.
    - Nelson.
    - Perkins.
    - Pinder.
    - Strother.
    - Sweat.
    - Thompson.
    - Ware.
    - Willis.
    - Wisby.
25. Shinnecock (New York):
    - Arch.
    - Beaman.
    - Bunn.
    - Cuffee.
    - Davis.
    - Harvey.
    - Kellis.
    - Scudder.
    - Thompson.
26. Werowocomoco (Virginia):
    - Allmond.
    - Langston.
    - Norris.
    - Sampson.
    - Wise.
27. Wesorts (Maryland):
    - Butler.
    - Harley.
    - Linkins.
    - Mason.
    - Newman.
    - Proctor.
    - Queen.
    - Savoy.
    - Swan.
    - Thompson.

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Recently Published Greek Papyri of the New Testament[1]

By Bruce M. Metzger, *Princeton Theological Seminary*

[With 8 plates]

How does an editor know what words to print in an edition of the Greek New Testament? In other words, what is the textual foundation of the New Testament?

Three main sources of information exist for our knowledge of the text of the books of the New Testament. They are the Greek manuscripts, the early translations into other languages, and the quotations from the New Testament made by early ecclesiastical authors. The earliest versions of the New Testament, prepared by missionaries to assist in the propagation of the Christian faith among people whose native tongue was Syriac, Latin, and Coptic, are of exceptionally great value to the textual critic of the New Testament. Scarcely less useful are the quotations from the New Testament in the commentaries, sermons, and miscellaneous treatises written by early Church Fathers for the explanation and defense of their faith. Indeed, so extensive are these citations that, if all other sources for our knowledge of the text of the New Testament were destroyed, they would be sufficient alone in reconstructing practically the entire New Testament.

Of these three main sources in the transmission of the words of the New Testament, the chief is, of course, the mass of Greek manuscripts, and it is with certain of these that the present article concerns itself. Before considering in some detail all the Greek papyri of the New Testament published during the past 15 years, it will be necessary to refer to (1) the materials on which they were written, (2) the external forms in which they have been preserved, (3) the scholarly methods of dating and editing such documents, and (4) statistics regarding the classification and number of the Greek sources of the text of the New Testament.

The Materials of Ancient Books

Clay tablets, stone, bone, wood, leather, various metals, potsherds (ostraca), papyrus, and parchment (vellum) were all used in antiquity to receive writing. Almost all the Greek sources of the New Testament are made of either papyrus or parchment.

The manufacture of papyrus was a flourishing business in Egypt. The papyrus plant grew plentifully in the shallow waters of the Nile at the Delta (see pl. 1). About 12 or 15 feet in height, the stem of the plant, which was triangular in cross section and as thick as a man's wrist, was cut into sections about a foot long. Each section was split open lengthwise and the pith cut with a sharp instrument into thin strips. A layer of these was laid down on a flat surface, all the fibers running in the same direction,

[1] Reprinted by permission from The Biblical Archaeologist, vol. 10, No. 2, May 1947, with several minor additions.

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and on top another layer was laid, with the fibers running at right angles to the lower layer. The two layers were then fastened together by moisture, glue, and pressure until they formed one fabric—a fabric which, though now so brittle that it can easily be crumbled into dust, probably had a strength nearly equal to that of good paper.

The manufacture of parchment for writing purposes has an interesting history. According to Varro, the learned Roman encyclopedist of the first century B. C., as reported by Pliny the Elder,[2] it was Eumenes of Pergamum, a city in Mysia of Asia Minor, who promoted the manufacture and use of parchment. This ruler, probably Eumenes II, who ruled from 197 to 159 B. C., planned to found a library in his city which would rival the famous library of Alexandria. This ambition did not please his rival, Ptolemy of Egypt (probably Ptolemy Epiphanes, 205–182 B. C.), who clamped an embargo on the export of papyrus sections. It was this embargo which forced Eumenes to develop the production of vellum, which from the place of its origin received the Greek name *pergamēnē* (whence our English word "parchment" is derived). Whatever may be thought of the details of this story, the core is doubtless true, namely, that a high quality of parchment was developed at Pergamum, so much so that the city became famous in the manufacture and export of this writing material and gave its name to the product.

Parchment or vellum—the two words are often used interchangeably, but exact writers restrict the word "vellum" to describe a finer, superior quality of parchment [3]—was made from the skins of cattle, sheep, goats, and antelopes, and especially from the young of these animals. After the hair had been removed by scraping, the skins were washed, scraped with pumice, and dressed with chalk. De luxe editions, according to St. Jerome, who did not approve of such extravagance,[4] were made of vellum dyed purple and written with gold and silver inks. Ordinary editions were written with black or brown ink and had headpieces and initial letters colored with blue or yellow or (most often) red ink—whence the word "rubric," from *ruber*, the Latin word for "red."

Vellum or parchment continued to be generally used until the late Middle Ages. At that time the use of paper made of cotton, hemp, and flax, having been introduced into Europe from China by Arabian traders, became popular and supplanted other writing materials.

The Form of Ancient Books

The manuscripts of the New Testament have been preserved chiefly in two forms, the roll and the codex (that is, the book form with leaves). The papyrus roll or scroll was made by gluing together, side by side, separate sheets of papyrus and then winding the long strip around a stick, thus producing a volume (a word derived from the Latin *volumen*, "something rolled up"). The length of such a papyrus roll was limited by convenience in handling the roll; the normal Greek literary roll seldom exceeded 35 feet in length. Thus an author was discouraged by factors beyond his control from writing a very long book. Each of Luke's books, the Gospel and the Acts, would have filled an ordinary papyrus roll of 31 or 32 feet in length. Doubtless this is one of the reasons why Luke—Acts was issued in two volumes instead of one (Acts 1:1).

On the roll thus formed the writing was arranged in a series of columns, each about 2 or 3 inches wide. The

[2] Pliny, Natural History, XIII, 21. (The whole section down to 27 deserves careful reading.)

[3] W. Lee Ustick, "Parchment and Vellum." The Library, a Quarterly Review of Bibliography, 4th ser., vol. 16, pp. 441–443, 1936.

[4] See his Preface to Job, and his Epistle XXII, 32 (to Eustochium).

height of the columns, which ran parallel to the stick on which the roll was wound, varied of course with the height of the original papyrus sheets. Sometimes, but not very often, the roll was written on both sides (see Revelation 5: 1); this was called an opisthograph.

The roll was relatively inconvenient to use. The reader had to employ both hands, unrolling it with one hand and rolling it up with the other as the reading proceeded. Moreover the Christian community soon discovered how laborious it was to try to find certain passages in their sacred books when written in roll form. Early in the second century the codex, or leaf form of a book, began to come into extensive use in the Church. This was made by folding one or more sheets of papyrus in the middle and sewing them together. Christians found that this form had a number of distinct advantages over the roll: (1) it permitted the four Gospels or all the Epistles of Paul to be bound into *one* book, a format which was impossible so long as the roll was used; (2) it facilitated the consultation of proof texts; (3) it was better adapted to receiving writing on both sides of the page, thus keeping the cost of production down.[5]

In about the fourth century the fashions of bookmaking changed. The less fragile vellum came to be substituted for papyrus as the material for the best books in codex form. Quite an art and a science of manufacturing books developed. Since the hair side of vellum is darker than the flesh side, it was discovered that the most pleasing effect upon the reader was obtained only when the separate sheets were not indiscriminately bound together in quires, but when the hair side of one page faced the hair side of the opposite page, and the flesh side faced the flesh side, wherever the book was opened. In writing on papyrus the scribe was accustomed to utilize the horizontal fibers on the recto side of the sheet as guide lines for his script. In writing on vellum he would score the surface with a blunt pointed instrument, drawing not only horizontal lines but two or more vertical lines as well for the margins of each column of writing. In many manuscrips these guide lines are still visible, as are also the small pin pricks which the scribe made first, thus outlining the ruling pattern on the vellum.[6] Different schools of scribes would employ various procedures of ruling and it is occasionally possible for the modern scholar to identify the place of origin of a newly discovered manuscript by comparing its ruling pattern (as it is called) with those in manuscripts whose place of origin is known.

In times of economic depression when the cost of vellum increased, an older manuscript would be salvaged and used over again. The original writing was scraped and washed off, the surface resmoothed, and the new literary material written on the surface. Such a book was called a palimpsest (which means in Greek, "re-scraped"). One of the half dozen or so most important vellum manuscripts of the New Testament is such a palimpsest; its name is codex Eph-

[5] C. C. McCown, in his helpful article, "The Earliest Christian Books," Biblical Archaeologist, vol. 7, p. 21, 1943, supplies a table of figures showing the relative number of extant codices and rolls of Christian and pagan works from the third and fourth centuries. Peter Katz suggests that the adoption by Christians of the codex instead of the roll was part of a deliberate attempt to differentiate Christianity from Judaism (Journ. Theol. Stud., vol. 46, pp. 61–63, 1945).

[6] There is even a science of pin pricks! See E. K. Rand, "Prickings in a Manuscript of Orleans," Trans. and Proc. Amer. Philol. Assoc., vol. 70, pp. 327–341, 1939; and L. W. Jones, " 'Pin Pricks' at the Morgan Library," ibid., pp. 318–326; "Where Are the Prickings?" op. cit., vol. 72, pp. 71–86, 1944; and "Pricking Manuscripts: The Instruments and Their Significance," Speculum, a Journal of Mediaeval Studies, vol. 21, pp. 389–403, 1946. Rand had earlier dealt with various methods of ruling manuscripts in vogue during the Middle Ages; see his study entitled "How Many Leaves at a Time?" in Palaeographica Latina, vol. 5, pp. 52–78, 1927.

raemi (see pl. 2). Originally written in the fifth century, this Greek Bible was erased in the twelfth century and many of the sheets rewritten with the text of a Greek translation of 38 treatises or sermons by a Syrian Church Father of the fourth century, St. Ephraem. (This was not the only time when the text of the Scriptures has been obscured by sermons.) By the application of certain chemical reagents scholars have been able to restore with some success the almost obliterated underwriting, although the task of reading it is most trying to the eyes. Sometimes palimpsests can be read by photographing them under infrared rays or with special fluorescent lamps.

The Dating and Editing of Manuscripts

How does a scholar determine the date when a Greek manuscript of the New Testament was written? In some medieval manuscripts the scribe would occasionally include certain personal and chronological information which enables the modern editor to reckon the scribe's date. But most manuscripts lack such scribal colophons, as they are called. Scholars are then compelled to judge the age of the document on the basis of its style of handwriting and artistic decorations (if the manuscript has such).

Until about the ninth century most books were written with large letters, quite like our capitals, called uncials. In the course of the centuries, however, these uncial letters became thick and clumsy. Then, in the ninth century, Theodore the Studite, or some of his associates in the monastery of the Studium in Constantinople, popularized a bookhand of small letters (minuscules is the technical name) as we write, in a running or cursive script. Because this script was adopted almost at once throughout the Greek world, manuscripts of the New Testament fall into two well-defined groups, the older being those written with uncial letters and the later with minuscule letters.

It is possible, however, to date manuscripts within much more narrow limits than is afforded by the distinction between large and small letters. Styles in handwriting change from age to age. Tables of typical letters of the alphabet have been drawn up from dated manuscripts of each century and even half century, and by comparing the script of an undated document with these it is possible to estimate its age with tolerable accuracy.

In addition to dating a manuscript, the editor of a newly found document will describe fully its external appearance and physical dimensions and condition. Further, he will make its text available to other scholars. This is done either by publishing the entire text as it stands or, more frequently, by publishing only those words or phrases which differ from a generally accepted norm. This process of comparing the text of the manuscript word by word and letter by letter with a printed text accepted as a standard is called collating the document, and the resulting collation supplies material for a critical apparatus of variant readings. When it has been observed that a number of manuscripts of the New Testament consistently agree in adding, omitting, or otherwise altering various words and phrases, such manuscripts are said to be related to each other in families or types of text. The final task of an editor is to seek to determine to which of the previously isolated families his newly discovered document belongs.

Statistics of Greek Sources of the New Testament

It is customary to classify the Greek manuscripts of the text of the New Testament into several categories, partly according to the material out of which they are made, partly according to their script, and partly according to the use to which they were put.

At first, editors of the New Testament used abbreviations of cumbersome titles to designate Greek manuscripts. Since no one system was agreed upon by all editors, it was exceedingly confusing to compare the

evidence in one critical apparatus with that in another. The first step in the direction of standardization of nomenclature was taken by a Swiss scholar, J. J. Wettstein, who, in his handsome edition of the Greek Testament published in 1751–52, employed a system of capital letters to designate uncial manuscripts and Arabic numerals to designate minuscule manuscripts. The system now in general use was elaborated by Caspar René Gregory, a native Philadelphian who, after receiving his theological training at Princeton, went to Germany where he became the world's foremost authority on New Testament paleography. His task of assigning official numbers to newly discovered manuscripts was taken over after the first World War, during which he lost his life fighting in the German army, by Ernst von Dobschütz [7] (see pl. 3), who has published various lists of newly assigned numbers in Zeitschrift für die neutestamentliche Wissenschaft.[8] Since the death of von Dobschütz in 1934, his successor, Walther Eltester, has continued to act as a clearinghouse and to assign numerals to manuscripts, but has not yet published any lists.

The fragments of manuscripts made of papyrus are commonly listed separately from those made of vellum or paper. So far, 54 numbers have been assigned by Gregory, von Dobschütz, and Eltester, but actually only 51 Greek papyri are known. It is customary to refer to papyri by the letter "P" followed by a small superior numeral. In some unaccountable way the number P^{42} was given by von Dobschütz to a Coptic fragment published by Carl Wessely in 1914.[9] Likewise P^{25}, which Grenfell and Hunt had published as P. Oxyrhynchus 1353, being made of vellum, was erroneously listed among the papyri by von Dobschütz but later was assigned another number by him (0206)[10]. In its place, according to Kenneth W. Clark's Catalogue,[11] von Dobschütz assigned a papyrus fragment of the Epistle of James. But in a letter dated November 28, 1946, Sir Frederic G. Kenyon kindly passed on to the present writer the disconcerting information which he had just received from Eltester in Berlin that this same fragment of James was designated P^{54}. Finally, P^{51} is still vacant.

The vellum manuscripts are divided into uncials of which 212 have been cataloged,[12] and minuscules, of which 2,429 have been cataloged. The uncial manuscripts which have been known for the longest time are commonly designated in a critical apparatus by capital letters of the Roman and Greek alphabets, and by one Hebrew letter (aleph). Thus, the two oldest vellum manuscripts, codex Vaticanus and codex Sinaiticus, both of the fourth century, are referred to, respectively, as B and aleph; codex Ephraemi is C. For uncial manuscripts discovered since the last letter of these alphabets had been assigned, Arabic numerals are used, preceded by a zero. The minuscules, since the time of Wettstein, as was mentioned above, are referred to by Arabic numbers.

A subsidiary class of Greek manuscripts, both uncial and minuscule (though the latter by far predominate in quantity), is devoted to lectionaries.

[7] Professor von Dobschütz' complete reworking of Nestle's Introduction is remarkable for its comprehensive scope and concise treatment (Eberhard Nestle's Einführung in das Griechische Neue Testament, 4te Aufl., Göttingen, 1923).

[8] Vol. 23, pp. 246–264, 1924; vol. 25, pp. 299–306, 1926; vol. 26, p. 96, 1927; vol. 27, pp. 216–222, 1928; vol. 32, pp. 185–206, 1933.

[9] Studien zur Paläographie und Papyruskunde, vol. 15, No. 233b, pp. 102–103, 1914.

[10] Zeitschrift für die neutestamentliche Wissenschaft, vol. 32, p. 192, 1933.

[11] A descriptive catalogue of Greek New Testament manuscripts in America, p. 79. Chicago, 1937.

[12] Only one of these, however, is entirely complete; it is codex Sinaiticus of the fourth century.

These are Church reading books containing the text of sections of the Scriptures which were appointed to be read on the several days of the ecclesiastical and the civil year, comprising, respectively, the synaxarion and the menologion (see pl. 4). Scholars have only recently begun to realize the importance of lectionaries in tracing the history of the text of the New Testament during the Middle Ages. Inasmuch as the form of the citation of the Scriptures in official liturgical books always tends to be conservative and almost archaic, lectionaries are valuable in preserving a type of text which is frequently much older than the actual age of the manuscript would lead one to suspect.[13] Although 1,678 lectionaries have been cataloged, only a comparatively few have been critically studied.[14] They are usually referred to by the letter "l" preceding an Arabic numeral.

Short portions of six books of the New Testament have been preserved on ostraca, or broken pieces of pottery used by the poorest people as writing material. Those which have been cataloged are 25 in number and are referred to by the Old English or Gothic letter "O" followed by a numeral. Thus, the treasure of which Paul wrote (II Cor. 4: 7) has been committed, in a quite literal fashion, to "earthen vessels"; worthless, castaway potsherds have been inscribed with the imperishable words of the Gospel (see pl. 5).

Finally, a curious but quite unimportant source of our knowledge of the Greek text of the New Testament is comprehended under a group of nine talismans, or good luck charms. These amulets range in date from the fourth to the twelfth or thirteenth century and are made of vellum, papyrus, clay potsherd, and wood. The superstitious use of talismans, so prevalent in the ancient world, was scarcely less popular—if we may judge from repeated remonstrance against them by ecclesiastical authorities—among the faithful than among the pagans.[15] Four of those cataloged contain the Lord's Prayer and the others include scattered verses from other parts of the Old and New Testaments. They are referred to by the letter "T" followed by a numeral.

In evaluating the significance of these statistics of the amount of Greek evidence for the text of the New Testament, attention ought to be given, by way of contrast, to the number of manuscripts which preserve the text of the ancient classics. The "Bible" of the Greek nation, and for which the largest number of manuscripts are available today, was Homer's Iliad. The most recent figures for this work are 288 papyri, 2 uncials, and 188 minuscule manuscripts.[16] Next in quantity of evidence are Plato with 23 manuscripts, Thucydides with 21, Hesiod with 20, and so on down to many authors who are represented today by only one manuscript. In contrast to these figures, the textual

[13] Thus, for example, the Psalter in the Anglican Book of Common Prayer retains a translation of the Psalms which derives from the Great Bible of 1539, having resisted all efforts to make it conform to the King James Version of 1611.

[14] The University of Chicago has been sponsoring the study of this long-neglected source of information about the text of the New Testament; President E. C. Colwell has projected a series of publications under the general title "Studies in the Lectionary Text of the Greek New Testament" to which the most recent contribution was made by the present writer under the title "The Saturday and Sunday Lessons from Luke in the Greek Gospel Lectionary" (Chicago, 1944).

[15] Thus, in addition to remonstrances by Eusebius and Augustine, the Synod of Laodicea issued a separate canon proscribing the manufacture and use of amulets: ". . . and those who wear such we command to be cast out of the Church." For these and other references, see "The Fever Amulet," edited by the present writer in Papyri in the Princeton University Collections, under the general editorship of A. C. Johnson, vol. 3, pp. 78–79, Princeton, 1942.

[16] For further details, reference may be made to my article, "Trends in the Textual Criticism of the Iliad, the Mahābhārata, and the New Testament," Journ. Biblical Lit., vol. 65, pp. 339–352, 1946.

critic of the New Testament is embarrassed by the wealth of his material. Furthermore, the work of many a pagan author has been preserved only in manuscripts which date from the Middle Ages (sometimes the late Middle Ages), far removed from the time at which he lived and wrote. On the contrary, the gap between the composition of the books of the New Testament and the earliest extant copies is relatively quite short. Instead of the lapse of a millennium or more, as in the case of not a few classical authors, we shall see below that only a century and a half separates the Apostle Paul's writing from the earliest copy of his letters extant today.

The Chester Beatty Papyri of the New Testament

Undoubtedly the most momentous news of the discovery of any New Testament manuscript, since Tischendorf in the middle of the last century came upon part of codex Sinaiticus in a wastebasket in the monastery of St. Catherine on Mount Sinai, was the preliminary announcement in The (London) Times, Nov. 19, 1931, pp. 13–14, that three of the oldest codices of the New Testament had been acquired by A. Chester Beatty from a dealer in Egypt. Each of the three documents has suffered from the ravages of time, but New Testament scholars are exceedingly thankful for the portions which remain.[17]

The first, to which von Dobschütz assigned the number P^{45}, comprises portions of 30 leaves of a papyrus book, which originally contained all four Gospels and Acts, measuring about 10 by 8 inches. Matthew and John are the least well preserved, each being represented by only two fragmentary leaves. Six leaves of Mark, seven of Luke, and 13 of Acts remain of these books. A part of this codex (fragments of the second leaf of Matthew) was discovered in a collection of papyri at Vienna.[18]

The second, designated P^{46}, comprises 86 leaves (all slightly mutilated) of a single quire papyrus codex which originally contained on 104 leaves 10 Epistles of Paul in the following order: Romans, Hebrews, I and II Corinthians, Ephesians, Galatians, Philippians, Colossians, I and II Thessalonians.[19] Today portions of Romans and I Thessalonians, and II Thessalonians in its entirety, are missing. The Pastoral Epistles were apparently never included in the codex, for there is not room for them on the leaves missing at the end. (Since it is a single quire codex, the number of leaves lacking at the end can, of course, be computed with precision).

It will be observed that, in addition to the reversal of the present order of Galatians and Ephesians, the Epistle to the Hebrews is among the genuine Pauline Epistles,[20] which are arranged in a general order of their decreasing lengths. P^{46} is noteworthy, likewise, in that the doxology to Romans (16:25–27), which in the earlier manuscripts stands at the end of chapter 16, and in the great mass of the later manuscripts at the end of chapter 14, is here placed at the end of chapter 15 (see pl. 6).

An instance of a variant reading in this third-century codex which has modified critical opinion as to what

[17] These were edited by Sir Frederic G. Kenyon, The Chester Beatty Biblical Papyri, Descriptions and Texts (London, 1933–1937).

[18] Edited by Hans Gerstinger, "Ein Fragment des Chester Beatty-Evangelienkodex in der Papyrussammlung der Nationalbibliothek in Wien," Aegyptus, Rivista Italiana di Egittologia e di Papirologia, vol. 13, pp. 67–72, 1933.

[19] Thirty of the 86 leaves of this codex are at the University of Michigan and were edited by Henry A. Sanders, A Third-Century Papyrus Codex of the Epistles of Paul (Ann Arbor, 1935).

[20] This papyrus, however, contrary to common opinion, is not alone in placing Hebrews immediately following Romans; in six minuscule manuscripts and in a Syrian canon composed about A. D. 400 it occupies this position (see W. H. P. Hatch, "The position of Hebrews in the Canon of the New Testament," Harvard Theol. Rev., vol. 29, pp. 133–151, [1936]).

Paul actually wrote is found in II Cor. 1: 17. The revisors of the American Standard Version were undoubtedly influenced by P^{46} at this point and rendered the verse, "Did I make my plans like a worldly man, ready to say Yes and No at once?" Except for three other pieces of scattered evidence, the whole mass of manuscripts, versions, and Church Fathers read, "Yes, yes and No, no." [21]

The third Chester Beatty papyrus of the New Testament, designated P^{47}, comprises 10 slightly mutilated leaves of a codex of the book of Revelation. Of the original book, estimated to have been 32 leaves in length, only the middle portion remains, containing the text of 9: 10–17: 2.

As was mentioned above, these papyrus codices of parts of the New Testament are of exceptionally great importance, for they antedate the oldest vellum codices of the New Testament by about a century. Expert paleographers date P^{45} and P^{46} early in the third century, and P^{47} somewhat later in the third century. Thus, to make it very concrete, we have today a fairly complete copy of Paul's letters to seven Churches written perhaps 140 years after the Apostle's death.

The question may be asked, How does the discovery of these three manuscripts modify our knowledge of the history of the transmission of the New Testament text? It may be said, first of all, that they emphatically confirm the general soundness of the text of the Greek Testament. They agree, by and large, with the text which the Church has always regarded as canonical. Their importance, moreover, is of the highest in shedding more light upon the vexing problems concerning the distribution and antiquity of certain types of variant readings. The papyri do not support wholeheartedly any one of the previously isolated types of families of New Testament text. To use the terminology popularized by Westcott and Hort, the text of P^{45} and P^{46} is intermediate between the Neutral and Western families of text of the New Testament, standing somewhat closer on the whole to the former than to the latter. The most recent textual analyses, refining those made by the editor of the papyri, regard P^{45} as belonging to a type of text current in the Fayyum-Gizeh region of Egypt and designate it the "pre-Caesarean" type of text.[22] With regard to P^{46} the latest scholarly opinion [23] holds that its text is to be classified in the subgroup of manuscripts which von Soden designated I^{a3}. The most exhaustive investigation of the textual affinities of P^{47} reveals it to be quite closely related to codex Sinaiticus of the fourth century and to the ninth- or tenth-century minuscule 1841, both of which represent a type of text current at Alexandria.[24]

Four Other Small Fragments of Papyri

In 1933 Yale University purchased a leaf of Egyptian papyrus which offers more than one intriguing problem. The leaf, which has been as-

[21] Simultaneously with the publication of the Revised Standard Version, a Jesuit scholar in Madrid, José M. Bover, came to the same conclusion in his "El 'SI' y el 'NO': Un Caso Interesante de Crítica Textual," Estudios Bíblicos, segunda época, vol. 5, pp. 96–99, 1946.

[22] See Teófilo Ayuso's thorough and painstaking study "¿Texto Cesariense o Precesariense?" Biblica, vol. 16, pp. 369–415, 1935. For a recent survey of investigation dealing with the Caesarean text of the Gospels, reference may be made to my article on this subject, Journ. Biblical Lit., vol. 64, pp. 457–589, 1945.

[23] See José M. Bover, ed., Novi Testamenti Biblia Graeca et Latina, pp. xlix sq., Madrid, 1943.

[24] José M. Bover, "¿El Códice 1841 (=127) es el Mejor Representante del Apocalipsis?" Estudios Eclesiásticos, vol. 18, pp. 165–185, 1944. For a summary and evaluation of the work done by the Hispanic scholars mentioned in the last four footnotes, reference may be made to the present writer's article in Journ. Biblical Lit., vol. 65, pp. 401–423, 1947, entitled "Recent Spanish Contributions to the Textual Criticism of the New Testament," which deals with about 40 books and articles published since 1925.

signed the Greg.-Dob. number P^{50}, contains a rather careless transcript of two portions of Acts (8: 26–32 and 10: 26–31), neither of which constitutes a well-rounded and complete pericope. Apparently the scribe wrote no more than this one sheet, folding it into a booklet of four pages. What was the purpose for which it was written and why were these portions of Acts chosen? After considering various possible reasons for the selection of these two Scripture passages—which are parts of the narratives of Philip and the Ethiopian Eunuch, and Peter and Cornelius—the editor, Carl H. Kraeling, concludes that perhaps it "was written in service of missionary or homiletic purposes or both. It may be the work of a Christian preacher culling from a New Testament codex—or for that matter a lectionary—materials for the instruction of his parishioners on the character and scope of Christian missions."[25] The editor dates the fragment in the middle of the fourth century.

The Rylands Fragment of John's Gospel

From many points of view the small fragment designated by the symbol P^{52} is of exceedingly great import. Measuring only 2½ by 3½ inches and containing but a few verses from the Fourth Gospel (18: 31–33, 37–38), it is the oldest fragment of the New Testament which has been preserved (see pl. 7). Although it had been acquired by Prof. Bernard P. Grenfell as long ago as 1920, it remained unnoticed among hundreds of similar shreds of Egyptian papyri until 1934. In that year C. H. Roberts, Fellow of St. John's College, Oxford, while sorting over the unpublished papyri in the John Rylands Library of Manchester, recognized that this scrap preserved sentences from John's Gospel. Without waiting to edit the fragment along with others of a miscellaneous nature, he immediately published a booklet setting forth a description of the fragment, its text, and a discussion of its significance.[26]

From the style of the script, Roberts dated the fragment in the first half of the second century.[27] It is, therefore, older by a century than the Chester Beatty papyrus of John and older by two centuries than the most ancient vellum codices, Hort's "heavenly twins," Vaticanus and Sinaiticus.

Although the papyrus is torn vertically so that more than half of the column of writing has perished, enough remains to enable scholars to restore with practically complete assurance the missing portion of each line. By comparing what remains with the printed text of the passage, it was soon discovered that each line had an average of 29 or 30 letters.

One of the first questions asked when reference is made to P^{52} is, How does the text of this earliest fragment compare with what editors have been accustomed to regard as the true text of John? Of course the paleographer, unlike the paleontologist who reconstructs a prehistoric man from a few molars and a piece of shin bone, cannot answer for what he does not have,

[25] "P^{50}, Two Selections from Acts," Quantulacumque, Studies Presented to Kirsopp Lake . . . , p. 171, London, 1937.

[26] An Unpublished Fragment of the Fourth Gospel in the John Rylands Library (Manchester, 1935). After republishing the fragment with minor alterations in the following year in the Bulletin of the John Rylands Library, vol. 20, pp. 45–55, 1936, Roberts published it a third time in his Catalogue of the Greek and Latin Papyri in the John Rylands Library, Manchester, vol. 3, pp. 1–3, Manchester, 1938, providing a bibliography of reviews and opinions expressed since the first publication of the papyrus.

[27] Although not quite all scholars are agreed that it can be dated within so narrow a range, Kenyon, W. Schubart, H. I. Bell, Deissmann, and W. H. P. Hatch have expressed themselves as being in agreement with Roberts' judgement. Indeed, Deissmann believes that it certainly was written within the reign of Hadrian (117–138) and may even date from the time of Trajan (died 117); see his "Ein Evangelienblatt aus den Tagen Hadrians," Deutsche allgemeine Zeitung, No. 564, Dec. 3, 1935, English translation in the British Weekly, Dec. 12, 1935, p. 219.

but as far as these few verses are concerned, their text agrees almost exactly with that of printed editions. With the exception of several variants which amount to no more than the difference between "honor" and "honour" or "theatre" and "theater," the only significant variant which does not appear in any other witness is the probable omission in verse 37 of the Greek words meaning "for this cause." This omission is almost certain, for if the two words involved in this variant had been originally present in the lost portion of the fragment, the number of letters in that line would be 38, whereas without them the number of letters is 30. The scribal omission (for thus it must be regarded) can be accounted for by supposing that the presence of the same two words in the preceding line confused the scribe who, overlooking the second occurrence of the phrase, copied only once what should have been copied twice (called technically, haplography).

Although the extent of the verses preserved is so slight, in one respect this tiny scrap of papyrus possesses quite as much evidential value as would the complete codex. As Robinson Crusoe, seeing but a single footprint in the sand, concluded that another human being, with two feet, was present on the island with him, so P^{52} proves the existence and use of the Fourth Gospel in a provincial town along the Nile, far from its traditional place of composition (Ephesus in Asia Minor), during the first half of the second century. Had this little fragment been known during the middle of the past century, that school of New Testament criticism which was inspired by the brilliant Tübingen professor, Ferdinand Christian Baur, could not have dated the composition of the Fourth Gospel in about 160.

In 1934 the University of Michigan acquired two leaves of a Greek papyrus from a dealer in Cairo. One leaf contains Matt. 26:29–35, 36–40, and the other Acts 9:34–38; 9:40–10:1. The editor, Henry A. Sanders, thinks it probable that the two leaves "were once parts of the same manuscript, which in that case perhaps contained the four Gospels and Acts" (as does P^{45}).[28] The text is without any specially noteworthy characteristics, being, in the opinion of the editor, a typical third-century text of Egypt. The number assigned to it is P^{53}.

Finally, to complete this list of all the Greek papyrus fragments of the New Testament which have been published since 1933, there is a fifth- or sixth-century leaf from Oxyrhynchus, acquired in 1928 by Robert Garrett, a banker of Baltimore, and containing some verses from the Epistle of James (2:16–18, 22–23, on one side, and 2:24–25; 3:2–4, on the other). The owner deposited the fragment in the Library of Princeton University where it was edited in 1936 by Edmund H. Kase, Jr.[29] As was mentioned above, this leaf has had the singular misfortune of having been assigned two different numbers, P^{25} by von Dobschütz and P^{54} by Eltester.

Along with this confusion of numbering, the fragment offers an interesting opportunity for detective work. A Greek numeral on each side of the leaf indicates that it was once pages 29 and 30 of a codex. What preceded it? Assuming that this codex contained the Catholic (or General) Epistles alone, the editor points out that "the fourteen missing leaves (pages 1–28) would have provided just enough space (making allowance for titles) for the three Johannine Epistles and the opening section of James (1:1–2:16)," but that "this space would be insufficient to accommodate the two Epistles of Peter in addition to the missing portion of James." In other words, it is likely that this

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[28] "A Third Century Papyrus of Matthew and Acts," Quantulacumque, p. 151. Sanders recognizes that the small size of the leaf would require some 250 leaves for the four Gospels and 75 for Acts (ibid., p. 153).

[29] Papyri in the Princeton University Collections, vol. 2, pp. 1–3, Princeton, 1936.

codex presented the Catholic Epistles in a most unusual sequence, one which is almost never met with elsewhere: I, II, III John, and James.[30]

Although the fragment now to be described is made of vellum and not papyrus, its intrinsic interest and great importance for one part of the textual criticism of the New Testament almost demand that it be included in an enumeration of the recently published papyri of the New Testament. Because of the special nature of the text of this fragment, a few words must be devoted to setting forth something about the origin of an early Christian document whose suspected influence upon the text of the Gospels in the course of their transmission has been investigated and variously assessed by many textual critics.

Tatian's Diatessaron[31]

Every attentive reader of the Gospels has observed that sections in each of the Four Gospels resemble more or less closely sections in one or more of the others. Particularly close in phraseology are parts of the Synoptic Gospels. In a day when books were not produced so rapidly or so cheaply as today, more than one early Christian scholar must have lamented the high cost of separate copies of all Four Gospels. Although many may have been distressed about this circumstance, the first, so far as we know, who did anything about it was a Syrian from Mesopotamia, Tatian by name. Deciding to make a harmony of the Four Gospels, he arranged the several sections of each Gospel into a more or less logical and chronological order, combining phrases preserved by only one Evangelist with those preserved by another. By omitting a very few sections (such as the genealogies of Jesus in Matthew and Luke, the former of which traces our Lord's lineage from Abraham downwards and the latter of which traces it backwards to Adam), Tatian preserved practically the entire contents of four separate books woven into one. Scholars have debated at great length whether the work was composed first in Tatian's native tongue, Syriac, or in Greek. The name by which it came to be known, Diatessaron, involves a Greek phrase meaning "through [the] four [Gospels]."

Tatian's work became quite popular. As late as the fifth century Theodoret, who became bishop of Cyrrhus or Cyrus on the Euphrates in upper Syria in the year 423, found that more than 200 copies of this harmony were in use within his diocese. Because Tatian had become heretical in his later life, and because Bp. Theodoret believed that orthodox Christians were in danger of being corrupted by using Tatian's harmony, he destroyed all of the 200 copies and put in their place the separate Gospels of the four Evangelists.[32]

As a result of Bp. Theodoret's zeal, and doubtless others like him, today the complete Diatessaron exists only in translations of the original. One of these is a commentary written by St. Ephraem (who was mentioned earlier in connection with a Greek palimpsest) on the Syriac text of Tatian's work, and in which he quoted extensively from the lost harmony. Unfortunately the Syriac text of St. Ephraem's commentary has also been lost, but in 1836 the Armenians of the Mechitarist monastery of San Lazzaro at Venice published a copy of an

[30] Kase incorrectly supposes that this sequence is unique; a Sahidic manuscript at Rome (Propag. Borg. 63) has the same order, and apparently does not contain any of the other Catholic Epistles (C. R. Gregory, Textkritik des Neuen Testamentes, vol. 2, p. 857, Leipzig, 1902).

[31] A staggering amount of literature has grown up dealing with problems involving Tatian's Diatessaron; the most complete recent survey is Curt Peters' 235-page treatment, "Das Diatessaron Tatians, seine Überlieferung und sein Nachwirken in Morgen- und Abendland sowie der heutige Stand seiner Erforschung," Orientalia Christiana Analecta, vol. 123, Rome, 1939.

[32] Theodoret, Treatise on Heresies, Book I, Chap. 20.

Armenian translation of the commentary. This has been made available for the use of scholars who are not expert in the Armenian language by a Latin rendering prepared by J. B. Aucher and edited by Georg Moesinger in 1876. Again, early in the sixth century Bp. Victor of Capua in Italy found an anonymous Latin harmony of the Gospels which he thought a descendant of that made by Tatian. The Bishop edited it, substituting, however, a Latin Vulgate text for that which he found. Bp. Victor's work is still extent in codex Fuldensis, written at the monastery of Fulda in 541–546. In addition there are Arabic and Persian translations, several medieval Dutch, Old High German, and Low German harmonies, a Middle English and two medieval Italian forms of harmonies, all more or less closely related to Tatian's work.

In the light of the foregoing it is not surprising that scholarly interest was aroused when it was announced in 1933 that a Greek fragment of Tatian's long-lost Diatessaron had been discovered. In an expedition conducted under the collaboration of Yale University and the French Academy of Inscriptions and Belles Letters on the site of the ancient fortress town of Dura-Europos on the lower Euphrates, a tiny scrap of the Diatessaron was unearthed (see pl. 8). Situated on the frontier of the Roman Empire, Dura-Europos fell to the Persians under King Shapur I in the year 256–257. During the few years prior to that date the Roman garrison within the city prepared for a siege by strengthening the city walls; they threw up against the inner face of the western city wall a huge embankment of earth, ashes, and rubbish. Covered by a layer of mud bricks and later by the desert sand which eventually spread over the entire city, various documents, most of them merely waste paper, have been preserved from the elements during the centuries. One of these is a vellum fragment measuring 3¾ by 4¼ inches and containing 14 imperfect lines of the Diatessaron in Greek. The date of the roll of the Diatessaron from which this shred came must, of course, be prior to 256, and it may be assigned with certainty to the first half of the third century.[33]

The text of the fragment contains the narrative of the coming of Joseph of Aramathea for the body of Jesus. A literal translation will show how words and phrases from all four Gospels are woven together. Since the left-hand margin of the vellum has suffered damage, the first half dozen or so letters at the beginning of each line are lacking. They can be restored, however, with almost perfect confidence. In the following rendering the restorations are enclosed within square brackets and the modern Scripture references (which are not, of course, in the fragment) are enclosed within parentheses.

"[. . . The mother of the sons of Zebad]ee (Matt. 27:56) and Salome (Mark 15:40) and the wives [of those who] had followed him from [Galile]e to see the crucified (Luke 23:49b–c). And [the da]y was Preparation; the Sabbath was daw[ning] (Luke 23:54). And when it was evening (Matt. 27:57), on the Prep[aration], that is, the day before the Sabbath (Mark 15:42), [there came] up a man (Matt. 27:57), be[ing] a member of the council (Luke 23:50), from Aramathea (Matt. 27:57), a city of Judea (Luke 23:51), by name Jo[seph] (Matt. 27:57), good and ri[ghteous] (Luke 23:50), being a disciple of Jesus, but se[cret]ly, for fear of the [Jew]s (John 19:38). And he (Matt. 27:57) was looking for [the] kingdom of God (Luke 23:51b). This man [had] not [con]sented to [their] p[urpose] . . . (Luke 23:51a)."

Evidently Tatian went about composing his Diatessaron with great diligence. Probably he worked from four separate manuscripts, one of each of the Gospels, and, as he wove to-

[33] The fragment was edited by Carl H. Kraeling in Studies and Documents, vol. 3, London, 1935.

gether phrases, now from this Gospel and now that, he would cross out these phrases in the four manuscripts from which he was copying. Otherwise it is difficult to understand how he was able to put together so successfully a cento of very short phrases from four separate documents.

The most spectacular reading preserved in this fragment is near the beginning. Although it rests partly on a restoration, and although none of the translations of Tatian which were known hitherto exhibits the reading, it is probable that Tatian referred to "the wives of those who had followed" Jesus from Galilee. This statement and the information which it conveys are without parallel in the text of the separate Gospels in any manuscript or version.[34]

Not long after the Dura fragment was discovered another leaf believed to be from an ancient Greek harmony was edited.[35] It is a page from a papyrus codex acquired by Professor Carl Schmidt in 1937 in Egypt and placed by him in the Berliner Staatlichen Museum. It measures only 4 inches high and 8¾ inches wide, and at least one half of the page has been lost. The editor dates the fragment at the turn of the fifth or sixth centuries. Although the text is from only one Gospel (it is Matt. 18:32–34; 19:1–3, 5–7, 9–10), the editor was led to suspect that it goes back to Tatian because of the presence of so very many unusual variant readings within so few verses, many of which agree with readings in the Latin, Arabic, and other forms of the Diatessaron.[36]

Conclusion

The study of the Greek papyri of the New Testament is part of the work of the textual critic. His work is fundamental to every other Biblical or theological inquiry. Before a text can be interpreted, systematized, or applied, it must first be made available in as pure a form as can be recovered. Moreover, besides being absolutely basic, the work of the textual critic is also more permanent than that of many other theological scholars. Unaffected by the ebb and flow of philosophical tides and the changing winds of doctrines, the painstaking labor of an accurate collator of Biblical manuscripts remains a lasting contribution to scholarship. In this field "the harvest truly is plenteous, but the laborers are few."

[34] Another minor difference is the absence of Matthew's characterization (27:57) of Joseph as "a rich man." The Arabic and Latin forms of the Diatessaron do not omit this trait. Have they added it to complete the harmony? Did Tatian have some sort of special antipathy against wealth?

[35] Otto Stegmüller, "Ein Bruchstück aus dem griechischen Diatessaron (P. 16,388)," Zeitschrift für die neutestamentliche Wissenschaft, vol. 37, pp. 223–229, 1938.

[36] The veteran polyglot investigator of the Diatessaron, Anton Baumstark, agrees with the opinion of Stegmüller; see his "Ein weiteres Bruchstück griechischen 'Diatessaron' Textes," Oriens Christianus, ser. 3, vol. 14, pp. 111–115, 1939 (he is not yet convinced that Greek was the original language of Tatian's harmony). On the other hand, Curt Peters, "Ein neues Fragment des griechischen Diatessaron?" Biblica, vol. 21, pp. 51–55, 1940, maintains that, although the Berlin fragment may show the influence of the Diatessaron, it is not itself a descendant of Tatian's harmony; so also in his "Neue Funde und Forschungen zum Diatessaron," ibid., vol. 23, pp. 68–77, 1942.

[illegible] with translations into the Latin, Syriac, and other forms of the Diatessaron.

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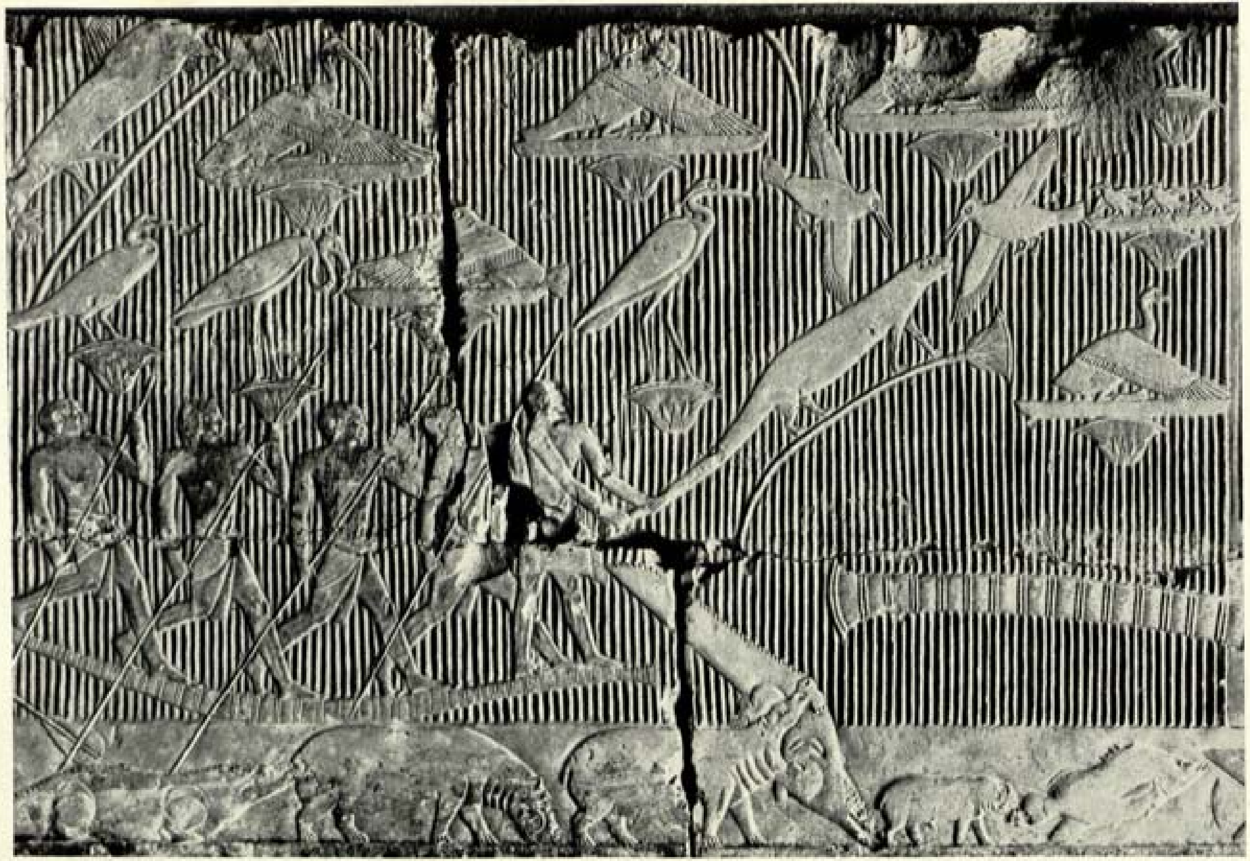
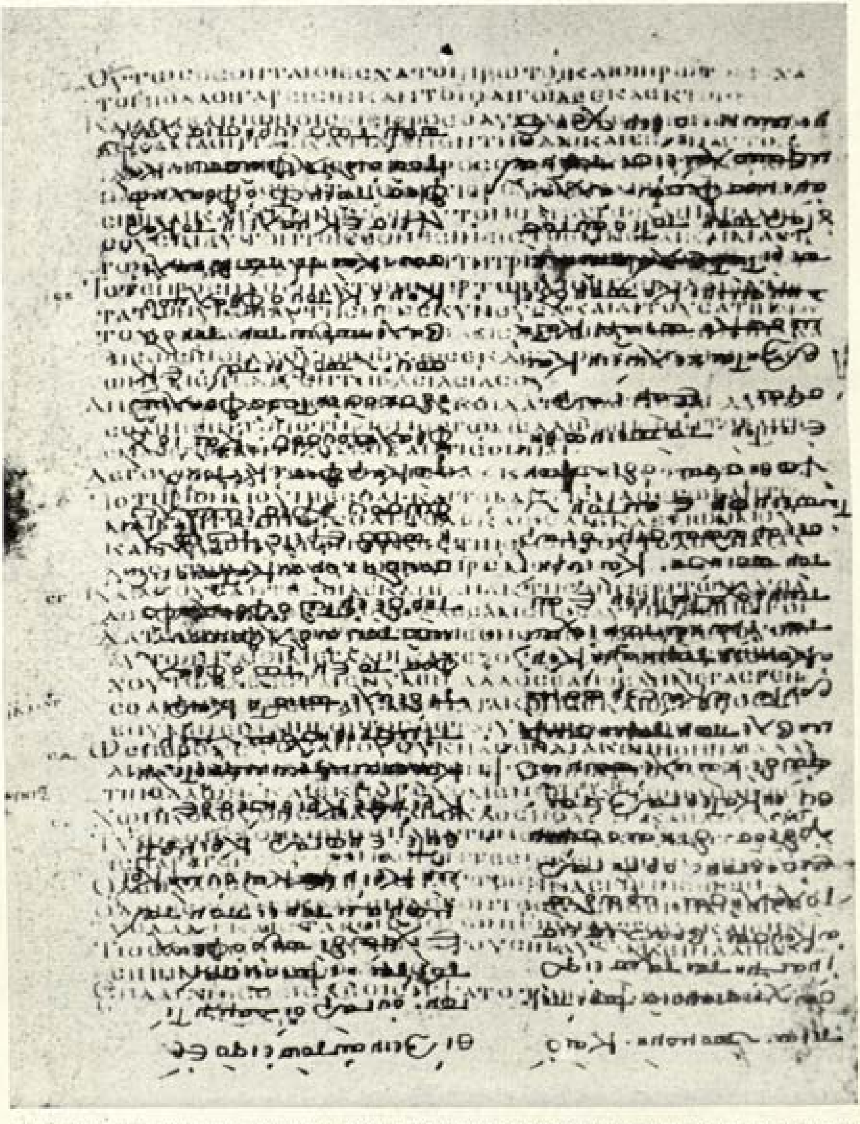


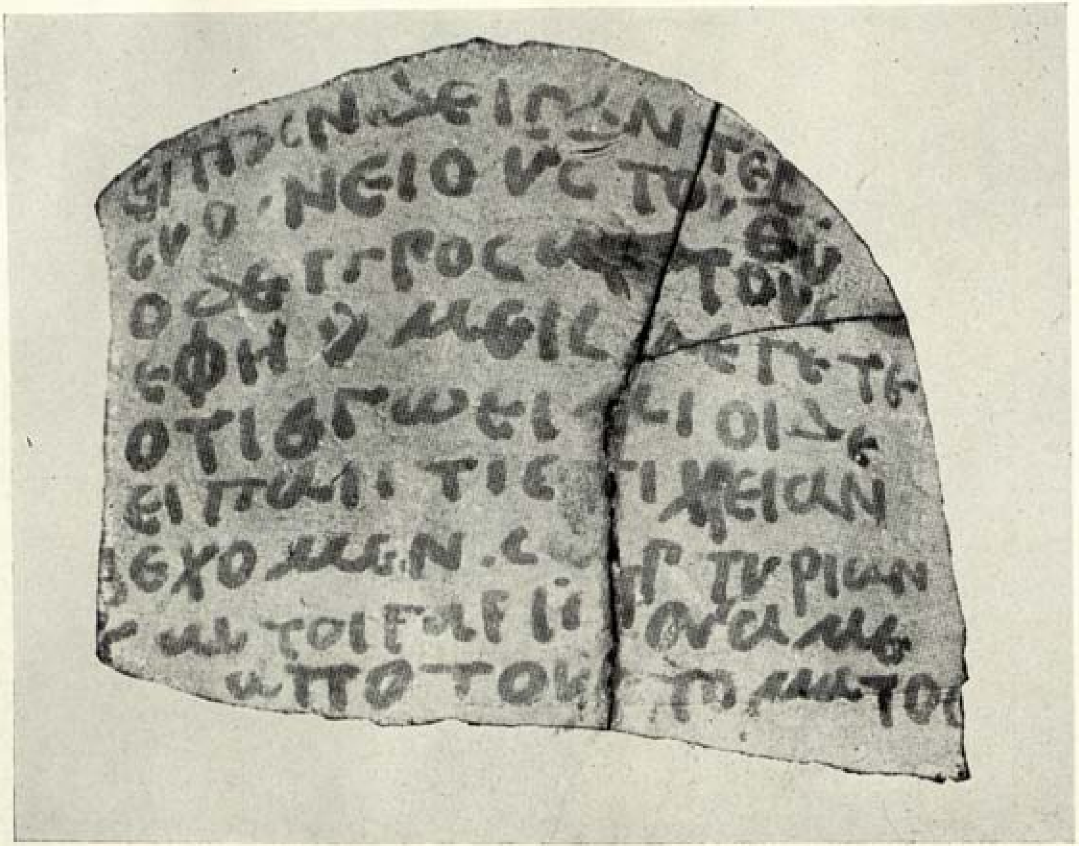
Bas-relief scene of an Egyptian papyrus marsh along the Nile, from the south wall of the tomb of Mereruka. The flowers and vertical lines represent the papyrus thicket. The etymology of the English word "paper" goes back to the Greek word for papyrus, which, in turn, is probably derived (according to H. S. Gehman, The Westminster Dictionary of the Bible) from an Egyptian word which signifies literally "that of the Pharaoh; meaning perhaps, the royal plant, or rather referring to the royal manufacture of writing material from the papyrus plant." (Courtesy of the Oriental Institute of the University of Chicago.)



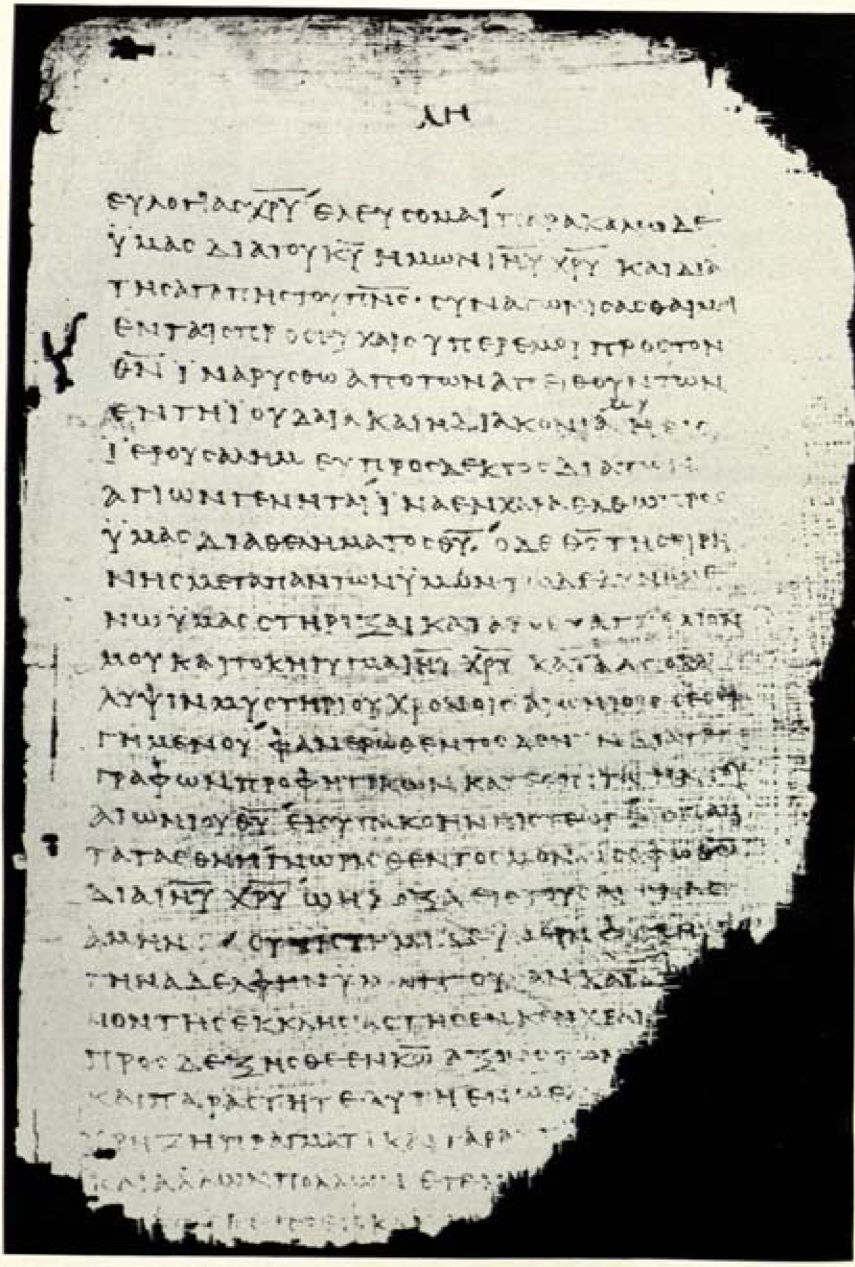
A page from codex Ephraemi rescriptus. The uncial text of the Bible was written in the fifth century but later was almost totally effaced to provide writing material for a twelfth-century transcription in minuscule script (which is upside down) of some treatises of St. Ephraem. (From Henri Omont, Facsimilés des plus anciens Manuscrits Grecs, pl. III, Paris, 1892.)

Prof. Ernst von Dobschütz, who succeeded Caspar René Gregory in the task of assigning official numbers to newly found manuscripts of the New Testament. (From Erich Stange, Die Religionswissenschaft der Gegenwart in Selbstdarstellungen, vol. 4, facing p. 31, Leipzig, 1928.)

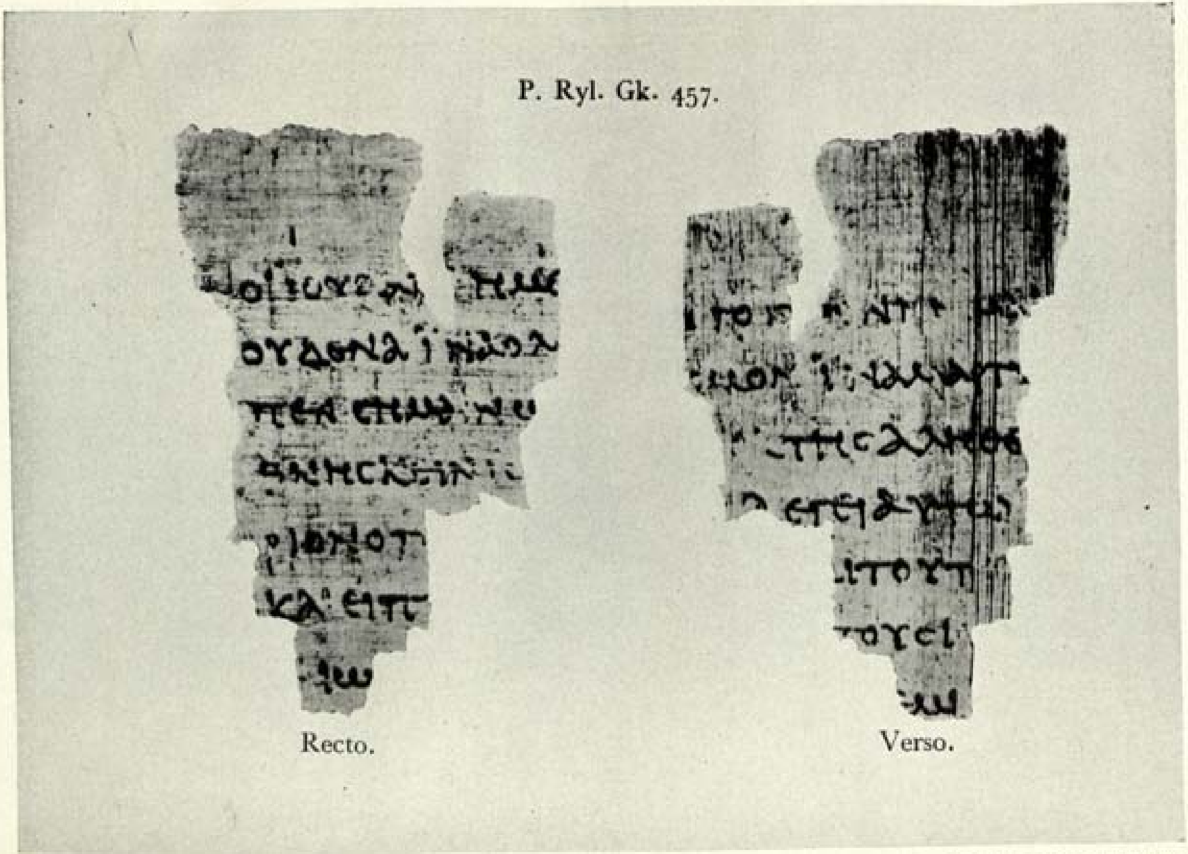
Illumination and text of the opening page of the Greek Gospel Lectionary 303, dating from the eleventh or twelfth century, now in the Library of Princeton Theological Seminary. The ornament, typically Constantinopolitan, is delicately colored with red, blue, green, yellow, and gold which have lost but little of their original brilliance. The gold title reads: "The Gospel of the Holy and Great Sunday of Easter, from the [Gospel] according to John." Then follows the pericope regularly read on this day, John 1:1-17. (A collation, prepared by the present writer, of the text of the Gospel lections for each day of the ecclesiastical year, called the synaxarion, is available on microfilm in the libraries of Princeton Theological Seminary and the Divinity School of the University of Chicago.)



Ostracon from Upper Egypt, inscribed with Luke 22:70 f. Probably written in the seventh century by a Christian peasant so poor that he could afford no better writing material than broken pottery salvaged from the rubbish heap. Now in the Institut Français d'Archéologie Orientale, Cairo. (From Adolf Deissmann, Light from the Ancient East, facing p. 50, London, 1911.)



A leaf from the earliest known copy of Paul's Epistles, the Chester Beatty Biblical Papyrus II (P^{46}), dating from the early part of the third century. This leaf contains the text of Romans 15:30–33; 16:1–3, a sequence not found in any other witness. The horizontal lines extending over groups of two or three letters mark the customary contractions of the *nomina sacra*, that is, the names of the deity and similar words. (From H. A. Sanders, A Third-Century Papyrus Codex of the Epistles of Paul, facing p. 35, University of Michigan Press, Ann Arbor, 1933.)



The two sides of a fragmentary leaf from a codex of the Gospel according to John, written probably between 100 and 150, being the oldest known copy of any book of the New Testament. (From C. H. Roberts, An Unpublished Fragment of the Fourth Gospel, frontispiece, Manchester 1935.)

Exterior view of the Palmyra Gate in the western wall of Dura-Europos, which fell before King Shapur I of Persia in 256–257. A vellum fragment of Tatian's famous Diatessaron was discovered in the rubble used to reinforce the interior wall less than a city block north of the gate. (From Franz Cumont, Fouilles de Doura-Europos (1922–23), Atlas, pl. XV, Paris, 1923.)

Japanese Art—A Reappraisal[1]

By Robert T. Paine, Jr., *Assistant Curator, Museum of Fine Arts, Boston*

[With 4 plates]

Most westerners are inclined to see in Japanese art a mere reflection of influences from the art of China. The Chinese, on the other hand, feel that Japanese art is disagreeably different. Common sense should indicate the natural conclusion that Japanese art is something distinctive, that its roots may have been transported from China, but its blossoms have developed a new variety in a new environment.

The seventh- and eighth-century Japanese became fully aware of the greatness of China. At the same time they realized their own national unity and power. They analyzed and imitated the Chinese administrative organization. They adopted ideas wholesale. In name they sought to follow the Chinese educational system, but whereas this was one of the democratic elements in Chinese life, in Japan it developed into an appendage of the aristocratic governing class. The artists of China may assuredly be grouped together as products of a rigid university training who, though they were philosophers, statesmen, and poets, also became painters. The biographies of the artists of Japan reveal origins among soldiers, aristocrats, churchmen, and craftsmen. The last group is in many ways the most important. Before the days of the direct imitation of Chinese institutions the artisans in Japan were organized into hereditary corporations. These craftsmen were made to fit into the feudal system of the Japanese. Their knowledge was that of technique and medium rather than in profundity of thought or charm of sentiment. When called upon, they illustrated the highest ideals of the age of their patrons, but they could seldom be classified as scholar-officials. Their traditionalism was handed on from generation to generation.

The first important history of Far Eastern art, Fenollosa's "Epochs of Chinese and Japanese Art," was written at a time when artists of the Kano family were still living in Japan. Fenollosa saw that there was a continuous tradition from his friend Kano Hōgai back to the days of Wu Tao-tzu, the most famous Chinese artist of the eighth century. Here was a single line stretching back for more than a thousand years. The school descends from the earlier ink monochrome painters of the fifteenth century, who in turn had done their utmost in Japan to revive the glories of the Sung period (960–1260) of Chinese art.

But, in the very study and appreciation of this backbone tradition which runs through the art of both China and Japan, much that is being praised today was omitted or undervalued by Fenollosa. This is particularly true of the later periods of Chinese art when the so-called literary man's art flourished. This school was influential in

[1] This article was first written in relation to an exhibition of Japanese art held at the Boston Museum of Fine Arts, and was published in the Bulletin of that Museum, vol. 46, No. 263, February 1948. It is here revised for a more general public.

Japan, too, in the eighteenth and nineteenth centuries. These developments in China and Japan seemed to Fenollosa "to lie below the level of mention."

On the other hand, the comparative scarcity of paintings belonging to the native Japanese tradition, types of art which, if their origin can be found in China, cannot be said to have developed there to any corresponding degree of importance, was not a result of inadvertence. Works of the medieval period, when this school was most predominant, have the intrinsic rarity of age.

The disproportion in quantity between the paintings of the "native" school and the "Chinese" school has facilitated the erroneous opinion that Japanese art is a mere imitation of Chinese art. Such medieval scrolls as the Burning of the Sanjō Palace or the Kibi's Adventures in China (details in pl. 1, figs. 1 and 2) are of immense importance not because they are especially old or rare, but because in them can be appreciated the art traditions of Japan when Chinese influence is not apparent.

In examining paintings of this class two facts stand out. They deal with history, fiction, biography, or some combination of these themes. They depict figures generally in lively action and exhibiting a wide variety of emotions. The interest created by the artist for his audience begins and ends with the human being and his emotions. This illustrative and figure art stands in marked contrast to the figure-in-landscape setting which dominates Chinese academic art or to the staid figure compositions which deal with Chinese moral or historical subjects.

The Japanese point of view is narrative and not philosophical, and the story-telling element is accompanied by incidental humor, lively detail, and a keen perception of the subjective relationship of one figure with another. To enhance the rendering in pictorial form active line work is enriched by strong color.

This same tendency reaches its climax in the popular prints of the Ukiyoé School. The productions are plebian and limited under the feudal regime to subjects which deal with the pleasures of life to the nearly absolute exclusion of any content which could have a political interpretation. Within this restricted field is the same characteristic of active line, strong color, and human interest which had expressed itself in the Yamatoé paintings of the medieval period. Indeed, many of the later print artists prefixed the words Yamato or Japanese-style painter to their signatures.

The print by Kiyomitsu (pl. 2, left) shows a woman dressing. It is one of those rare subjects in which the Japanese and Western attitudes nearly coincide. There is a suggestion of the physical beauty of the feminine figure quite apart from the usual charm of rhythmic drapery line. The response here subtly evoked appeals to our emotions, not to our heads. The interest is direct, not based on an intellectual comprehension backed by academic learning.

Between the medieval scroll painting and the mature print came the decorative school, another phase which expressed itself in art forms of purely Japanese development. The major works of Kōetsu, Sōtatsu, and Kōrin, which roughly cover the seventeenth century, present a tradition in the use of brilliant color, flatly applied in large areas, which is hardly to be found in any other artistic heritage. The use of gold grounds for screen paintings became common. Both in physical form and manner of treatment there has been created one of the great original art traditions which has graced the culture of a people.

The pair of flower screens by Sōtatsu (detail in pl. 2, right, upper) and the famous wave screen by Kōrin reveal an interest in nature which seems particularly Japanese. It would be dif-

ficult to find in Chinese art a seascape thus treated for its own sake. In the same way these flower paintings are decorative transcriptions from nature without any admixture of the animals or insects which so generally appear in Chinese paintings of this kind. Again, the Japanese love of nature, that sense of joy in the actual world around them, presents itself without the addition of elements dependent on a foreign philosophy.

Too frequently the question of the origin of an art has been emphasized more than that of the meaning of the art to the people for whom it was made. When one considers the amount of Buddhist art which has survived in Japan even from the eighth century and contrasts this fact with the scarcity of extant Buddhist paintings from Central China, the idea arises that for long periods the Japanese were more pious believers than the Chinese. Religious art is definitely emotional. In China its thoughts were opposed by the dominant Confucian tradition. Again, one finds in Japan the emotional preferred to the rational or philosophic attitude. The great paintings of the Shingon sect are difficult for us to appreciate just because they are dominated by foreign dogmas about the magical powers to be attached to word or form, yet these beliefs harmonized closely with the ritualistic attitudes common from the ninth to the twelfth centuries.

In the later Pure Land sects of Buddhism in Japan in which the doctrine of salvation by faith, and faith only, was insisted upon, one finds a favorite subject of Buddhist sculpture and painting in the descent of Amida from heaven (pl. 2, right, lower). His attendant bears a lotus throne, symbol of the believer's place in the heaven in the west. This type can be traced back to episodic details on the border of an early Chinese painting, but as an independent subject China does not seem to have produced any rendering so illustrative of single-hearted faith as do the Japanese representations.

In any discussion of Japanese art as a whole it would be impossible to omit the influence of the Zen religion. This was known especially in certain parts of South China. In Japan its influence extended through much of the aristocratic and samurai classes for centuries. This religion discards reason entirely in favor of intuition. Meditation, concentration, immediate apprehension, the acceptance of this world as it is, dominate any logical interpretation of life. The religious art of Japan furnishes another indication of the importance of emotion in the arts which seem particularly to express Japanese character.

The painting in ink monochrome attributed to Geiami (detail in pl. 3, fig. 1) is a type which can be fully traced back to China, but whereas the tradition was localized and short-lived in China, it evoked some profound trait of the Japanese soul and became for centuries an influencing factor in the official schools of painting. Such a painting reflects the thought of complete religious understanding in the body of a humble attendant. Most of the arts of this Renaissance period can be described as idealistic. The themes of the painters treat of Chinese scenes, of compositions in terms of Chinese philosophy, and of modes of rendering which have been stimulated by the study of ancient Chinese originals in collections which had only recently been formed.

If this appraisal of the major arts is true, then the same characteristics should be found in the minor arts, too.

The Ashikaga period (1392–1568) saw the rise and development of the Nō dances and as part of their equipment the creation of a new type of mask. For these, in direct contradiction to most of the arts, there is no counterpart in China. The taste of the Japanese, unhampered by continental influence, can here be traced.

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The masks, carved of wood and covered with gesso and lacquer, portray characters often chosen from the traditions of Japan, in plays written by Japanese authors. In them are frozen particular features or particular emotions. The jolliness of age, the jealousy of woman (pl. 3, fig. 2), the sorrowing spirit of a ghost are represented not in the realistic spirit of western individuality, but in a more classic balance. A typical human feeling is weighed against traditional ethic values whether they be Buddhist karma, feudal loyalty, or family responsibility. These sculptured portraits of emotional types, often too subtle for us in the West to recognize with ease, became in the hands of the Japanese carver an art form not paralleled elsewhere and one also superbly illustrative of a national esthetic attitude. The face of the human being, beautiful, manly, happy, or suffering, has a worldly value in plays of ethical content.

On a minor scale the netsuké of Japan illustrate to perfection the narrative style of figure treatment as opposed to the more symbolic Chinese method.

The costumes which the Nō actors wore also reveal a taste in elaborate textiles which for gorgeousness of color, freedom of patterning, and elaboration of technique mark a distinct departure from any produced on the continent. The Nō robe (pl. 4, fig. 1) impresses one first by its brilliant color, next perhaps by the effective quartered background. Cloud designs are woven with various colored extra wefts. The gold waves are done in gold brocading. The ship sails and pine branches are long floats of flossy silk. The quartering effect is achieved by the use of predyed warps. Sumptuous patterning is brought about in the ground itself, in brocading and especially in the loose embroidery-like floats of bright silk threads. Technical mastery combined with a feeling for materials gives a special character to the Nō robes.

The nationalism of Japan's so-called minor arts has never been questioned or compared disparagingly to those of China in the fields of sword making or of lacquer work. The virtue of a comprehensive exhibition of many of the arts of Japan lies just in this fact that the more varied the arts studied, the clearer becomes the picture of the original aspects of Japanese achievement.

Only after one has analyzed for oneself the salient Japanese characteristics can one look at works of art painted by Japanese in the Chinese manner and perhaps see them with Chinese eyes, so that these paintings appear distinctly different. To take an example, the epitomizing, staccato manner of Naonobu (detail in pl. 4, fig. 2) reveals a tenseness of approach which runs counter to the attitude so often expressed about Chinese pictures—that painting is poetry and poetry painting. It is the emphasis on and the interest in visualization which gives a peculiar charm and power to these sages. Ink values, reduced nearly to dark and medium tones, become a mode of interpretation. The imagination which produced these values is close cousin to that displayed by the great decorative school painters of Japan.

For a long time people have tried to explain Japanese art in terms of Chinese culture. The art of any nation which has had a true renaissance period may justifiably be compared with that of its prototype, but are the arts of Italy belittled because there was a time when the arts of ancient Rome or of Greece seemed of paramount importance in forming a new style? If one insists that only a people who have produced a great philosophy can produce a great art, then perhaps it would be possible to claim a superiority for the art of China. Yet to all who believe that art itself is a kind of vitalizing intuition, the art of Japan will appear in its proper original aspects and will measure against the other great art traditions of the world.

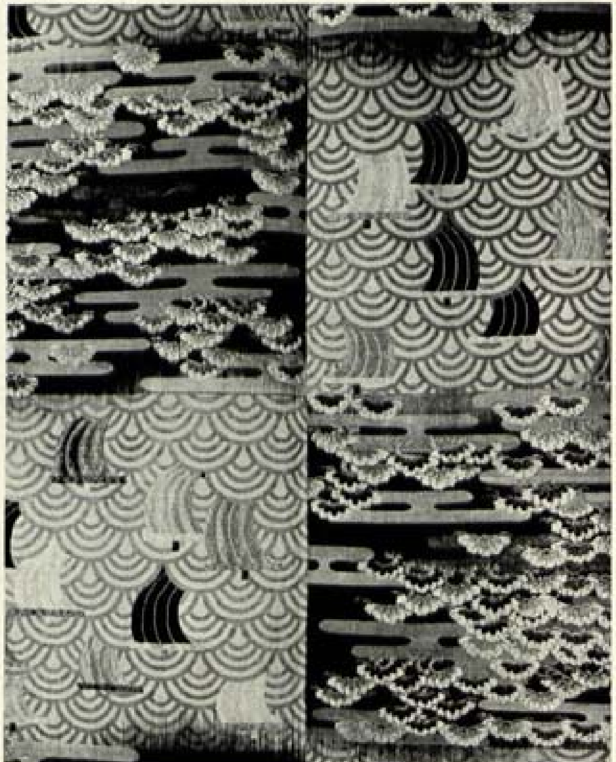
1. The Burning of the Sanjō Palace (detail). Thirteenth century.

2. Kibi's Adventures in China (detail). Twelfth century.

Left: Woman Dressing After a Bath. Kiyomitsu (1735–1785). Right, upper: Poppies (screen, detail). Sōtatsu (died 1643); lower: Amida and Twenty-five Bodhistattvas (detail). Thirteenth century.

1. Jittoku (detail). Geiami (fifteenth century).

2. Mask—Hannya. Late eighteenth century.



1. Nō robe (detail). Eighteenth century.

2. Po I (screen, detail).
Naonobu (1607–1650).

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